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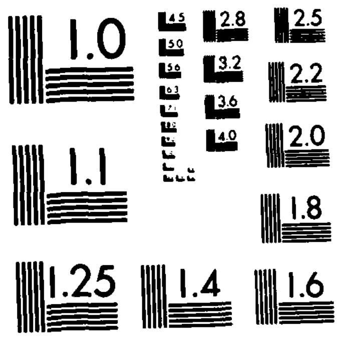

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THESIS

AAW FIREPOWER INDEXING FOR NAVAL COMBATANTS

by

Alan Douglas Zimm

September 1983

Thesis Advisor: W. Hughes

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REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER / 2. GOVT ACCESSION NO. AD-A138281	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) AAW Firepower Indexing for Naval Combatants	5. TYPE OF REPORT & PERIOD COVERED Master's Thesis; September 1983
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Alan Douglas Zimm	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Postgraduate School Monterey, California 93943	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Postgraduate School Monterey, California 93943	12. REPORT DATE September 1983
	13. NUMBER OF PAGES 200
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report)
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Anti-aircraft defense systems, anti-ship warfare, anti-ship cruise missiles, air defense, naval vessels, firepower indexing, simulation, mathematical models.

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A simulation is developed (Linear Anti-ship Missile Air Defense Simulation, or LASMADS) which models ship defenses under ASCM attack. Using this simulation, a firepower index is developed for current naval ships. The firepower index is used in a deterministic model which predicts the results of the ASCM-Surface ship engagement, and is responsive to the most important attack and defense characteristics and

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Special
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AAW Firepower Indexing For Naval Combatants

by

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Lieutenant Commander, United States Navy
B.S., University of California Los Angeles, 1972

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN OPERATIONS RESEARCH

from the

NAVAL POSTGRADUATE SCHOOL
September, 1983

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ABSTRACT

A simulation is developed (Linear Anti-ship Missile Air Defense Simulation, or LASMADS) which models ship defenses under ASCM attack. Using this simulation, a firepower index is developed for current naval ships. The firepower index is used in a deterministic model which predicts the results of the ASCM-Surface ship engagement, and is responsive to the most important attack and defense characteristics and variables. Uses of firepower indexes as an operational planning tool is discussed.

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I. INTRODUCTION

A. FIREPOWER INDEXING

The use of a single numerical value as an approximation of the combat power of a military unit has been used with success in models of land combat. Usually this procedure involves assigning a firepower score for each specific weapon system available to the unit and summing these values to obtain a composite force "firepower index." This firepower index is considered to be representative of the military capability or value of the aggregate unit. In most operational large-scale ground combat models, these values are important inputs in determining engagement outcomes, assessing casualties and approximating the movement of the lines of battle. These values are also used in Lanchester-type attrition models with some success. Taylor [Ref. 1] and Dupuy [Ref. 2] give extensive examples and make use of firepower indexing.

The use of firepower indexing for naval applications has met with less acceptance. The reasons mostly revolve around the issue of the number of components which are aggregated into a unit. In an army formation, there are large numbers of individual systems. In reality, each of these individuals will perform differently, even given the same equipment and training; however, by the law of large numbers, the net

performance of the formation would be expected to approach a certain mean value. Thus, the assignment of a single value for a unit can be rationalized, and is probably necessary for many of the large-scale applications in which it is used.

In contrast, in a naval unit there are relatively few individual combat systems, far smaller numbers and redundancies, and a highly centralized (and vulnerable) control facility with relatively few decision makers. The law of large numbers is not applicable to an individual naval unit. Consequently, there is the probability of wide variance in the performance of similar units. In addition, naval units do not degrade gracefully when subjected to battle damage. While it is reasonable to assign an army unit a one or two percent degradation due to combat losses, a cruise missile or torpedo hit on a destroyer or frigate will usually exhibit an "all or nothing" result. A single hit can elicit a wide range of results. The numerically small number of hits in a naval engagement are another source of variance.

Such sources of wide variance discourage use of any scheme of battle results calculation which tends to give expected value results. With the smaller number of units, small number of systems on each unit, and relatively small number of attacking weapons, the determination of the results of naval combat has usually been approximated by using computer simulation. A high-speed computer can resolve an entire missile engagement for a battle fleet in extraordinary detail.

B. POSSIBLE USES OF FIREPOWER INDEXING OF NAVAL SHIPS

Even with modern high speed computers there are limitations on the utility of detailed simulations, particularly in wargaming on a global basis. For example, the Naval Warfare Gaming System (NWGS) installed at the Center for Wargaming at Newport, Rhode Island, resolves naval engagements by stochastic simulation using human input for most engagement/fire decisions. In large scale, global games involving thousands of units and large ratios of time compression the computer system can become overloaded. The requirement for human interaction slows the process and places disproportionate demands for human attention to resolve engagements on a unit level. In this application alone there is a need to determine expected combat results by a method other than direct simulation. Firepower indexing could be used to meet this requirement.

Determining combat results based on firepower indexes has benefits in addition to saved computer time. First, it tends to clarify the question of relative value: an index twenty percent larger in one vessel than another implies twenty percent more combat value, a useful and easily-grasped measure. Second, the process of determining the firepower index in itself tends to illuminate those factors which optimize the combat value of a unit, and thus can be reflected in ship design. Third, firepower indexing simplifies

the approach to "how much" questions: how much air defense capacity is necessary to deal with a given air threat? How much anti-submarine capability is required for an advance into a specific threat area? Fourth, the determination of firepower indexing opens the way towards the possibility of attrition modeling using differential, or Lanchester equations, with their great utility in campaign analysis.

C. EXTENT OF THIS PROJECT

Naval warfare can be divided into three generic areas of interactions: anti-submarine, anti-surface, and anti-air. Specific equipment on board a ship often is specialized to operate in one and only one of these areas: a surface-to-air (SAM) missile has no anti-submarine capability, just as a torpedo has no anti-aircraft value. In some cases, entire ships are designed with one area of combat in mind with only limited capabilities in the other areas. This suggests that firepower indexing of naval units should have separate values for each type of warfare. Otherwise, the specialized nature of most platforms would be lost in the aggregating process.

This research has been directed toward developing a firepower index for ships in the field of anti-air warfare. The specific work was performed by considering area and point defenses of ships when under attack by anti-ship cruise missiles (ASCM), and was formulated using the results of extensive simulation backed up by theoretical computation.

A second objective was to apply these firepower indexes into a deterministic model which could be used to give combat results. The objective was to make this model small and simple (and thus easily used on micro-computers) and yet responsive to the major variables in an attack.

This work is by its nature inaccurate and incomplete.

Inaccurate because the basic information required to develop "accurate" results is mostly classified. Even within the classified sources there is considerable debate as to system responses, kill probabilities, effect of jamming, and the entire range of performance-related parameters. Consequently, rather than attempt to prove "the number" a more useful approach would be to demonstrate and validate a method, incorporating sufficient flexibility in the approach to allow specific tailoring to the numbers of the specific situation. Consequently, the numbers for "generic" systems using values obtainable in open-source literature were used.

Incomplete because as with all models, only those combat variables which were assumed to have a direct, significant, first-order effect of the outcome of the engagement were investigated. The study was primarily hardware-oriented, since the equipment was assumed to be functioning at capacity and uniformly, and that performance was not degraded by communications or command-and-control difficulties. Some suggestions for incorporating these factors are discussed

but were not investigated. In addition, in most cases independence was assumed between the influence of the effects. The exploration of the various parameters, without the assumptions of independence (if visualized as a graph, the "space between the axes"), might be a fruitful area for later investigation.

Consequently, attention should not be concentrated on the individual numbers and combat results. Rather, the salient concepts are the utility of naval firepower indexing, and the realization that these indexes can be used in a simple deterministic model which can reproduce the combat results of more detailed simulations.

Because any accurate use of these models will require application of the methodology using "actual" performance figures, no attempt was made to prove out any particular set of numbers. For that matter, once the models were developed to the point where a reasonable set of results were attained, no further attempt was made to fine-tune the parameters in order to achieve a close fit along all dimensions of investigation. Instead, the concentration is on the methodology. With the concepts and results presented, actual system performance values can be used to generate "real" values.

D. OUTLINE OF THE GENERAL COURSE OF THE INVESTIGATION

There were four basic steps taken in the course of the research.

The first step was to create a simulation of the ASCM-surface ship combat. The simulation was designed to incorporate most of the major factors influencing the engagement. Because of the number of variables to be investigated, and the concomitant requirement for a very large number of runs, the simulation was simplified as much as possible in order to reduce computer run time.

The second step was a combination of two processes. The simulation was exercised extensively to determine the response of the results of the engagement when individual parameters were varied. A base-case engagement was stipulated, and experiments were run. For instance, to determine the effects of radar detection range, scenarios were replicated using progressively longer detection ranges.

Concurrent with the experimentation was application of theoretical calculations. Theory was used to both identify those parameters which would have first-order effects on the result, and to predict and justify the results of the experiments.

Once a thorough understanding of the problem was achieved, the third step was to isolate and quantify those factors having first-order effects.

The fourth step was to combine these values into a simple, deterministic model. The results of the model were compared to the results of the simulation to test for comparability of results.

The area of firepower indexing for naval ships is a large and relatively unexplored area. This work only begins to attack the problem. Consequently, suggestions are included for improvements to the work already performed, and areas needing additional treatment will be indicated. These comments are included in the body of the paper and formal recommendations summarized in Appendix A.

II. LINEAR ANTI-SHIP MISSILE AIR DEFENSE SIMULATION (LASMADS)

A. PURPOSE AND OBJECTIVES OF THE SIMULATION

Most simulations of air defense are geometrically detailed, "next-event" type simulations. They account for, in precise detail, every event which could possibly require or allow action. Through attention to detail they are very precise simulations.

For the purposes of this research there were several disadvantages to most of these simulations:

* SIZE: Most of the programs run into the tens of thousands of lines, and are usually designed for one specific purpose. The size and complexity of the programs precluded either tailoring output or modifying the program to explore parameters different from those specified originally.

* RUNNING TIME: Performing 1000 replications of an ASCM attack on a typical battle group using one of the current air defense simulations on an IBM 360 (or similar generation computer) will take on the order of three to six minutes of running time. To explore the dimensions of the problem would require several hundred runs. Consequently, a simulation requiring less CPU time was desirable.

* SHIP DAMAGE: Many of the simulations do not incorporate battle damage or factor in immediately the effect of the damage on the air defense situation.

* EASE OF SETUP/FLEXIBILITY OF OUTPUT: Many simulations require an extensive amount of set-up activity, and are restrictive in the amount and types of information available in output. The large and varied number and types of scenarios required a simulation which could be easily and rapidly set up and would be compatible with a wide variety of outputs.

Consequently, a new simulation was written to accommodate those ends.

B. BASIC ASSUMPTIONS

1. Single Axis of Attack

ASCMs launched by a single unit or several units co-located will approach the target from a single direction. For the target unit the geometry of defense can be reduced to a one dimensional problem with the distance from target the parameter. This dimension will be referred to as the RANGE AXIS. By reducing the problem to a single geographic dimension (range), there is a great simplication in the program and reduction in the required calculations. A major reduction in program run time over three dimensional simulations was achieved: instead of three to six minutes to resolve an attack on a battle group, the LASMADS simulation run time was on the order of five to ten seconds.

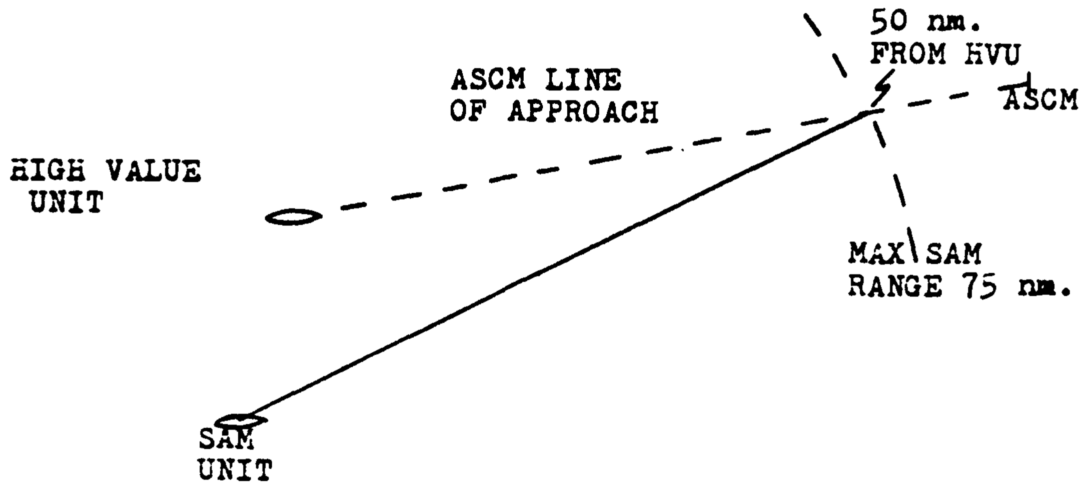
Another assumption was that the focus of the attack would either be the high value unit(s) at or near the center of the formation or the centroid of the formation

itself. By this assumption most of the ASCMs can be considered to be following the same flight path from launch point toward the center of the formation.

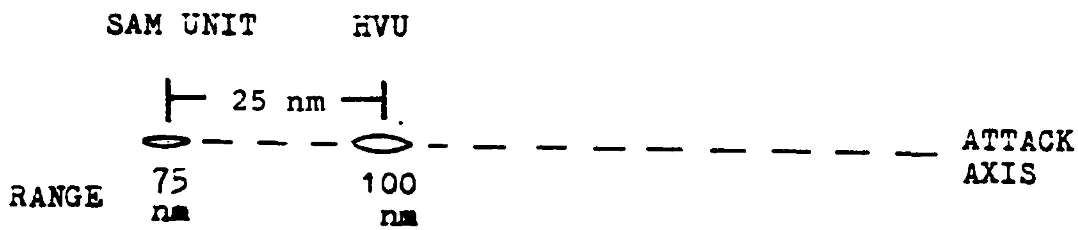
The requirement of the simulation would then be to determine the positioning of the ships in the formation along the range axis. The procedure would be to plot the formation two dimensionally; determine the direction of the attack; and to project the ships in the formation onto the axis of attack so that the same amount of their missile envelope which would be available to intercept missiles targeted against the high value unit extends in front of the high value unit.

Figure 1 is an example which demonstrates this procedure for two ships, the High Value Unit (HVU) and a SAM firing ship. The SAM missile ship has a missile with a maximum intercept range of 75 nautical miles (nm). It is positioned away from the HVU and off the axis of attack a sufficient distance so that only 50 nm of the missile envelope is available to defend the high value unit.

Consequently, the SAM missile ship should be placed on the range axis 25 nm further away from the origin of the attack than the HVU. If a convention is used where the attack always comes from the right of the range axis, and the HVU was (arbitrarily) assigned the position of 100 nm along the range axis, the SAM missile ship would be placed at position 75 nm. In that position 50 nm of the missile



A. Three Dimensional geometry of attack



B. Equivilent one dimensional representation

Fig. 1. Procedure for Reducing a Two-Dimensional Formation to One Dimension, for use in the LASMADS Simulation.

envelope would be available to protect the high value unit, while a missile actually targeted against the SAM ship would still be subject to the full 75 nm envelope of the SAM.

An additional factor to be considered is the effect of the intercept angle on the effective kill probability (P-K) of the defending missile. The fusing of SAM warheads is usually optimized for a shallow angle of intercept; intercepts at angles greater than, for example, 40 degrees, would show a smaller kill probability.

To take this into account, besides indicating the position of the ship, the axial position of the ship is assigned: whether it is on the attack axis or to the left or right (in effect dividing the defense into three planes). Ships on the plane to the left of the attack axis are coded with a "0"; those on the attack axis are coded with a "1"; and those on the plane to the right of the attack axis are coded with a "2". This procedure is illustrated in Fig. 2. An off-angle degradation factor (OADEG) was included as a specifiable parameter. If and only if the incoming ASCM had as a target a ship on a plane different from the plane occupied by the ship engaging that ASCM, an angled intercept was assumed. The P-K was reduced by the off-angle degradation factor, or twice the OADEG if the target and shooter were separated by two planes. For this work an OADEG factor or 0.15 was used.

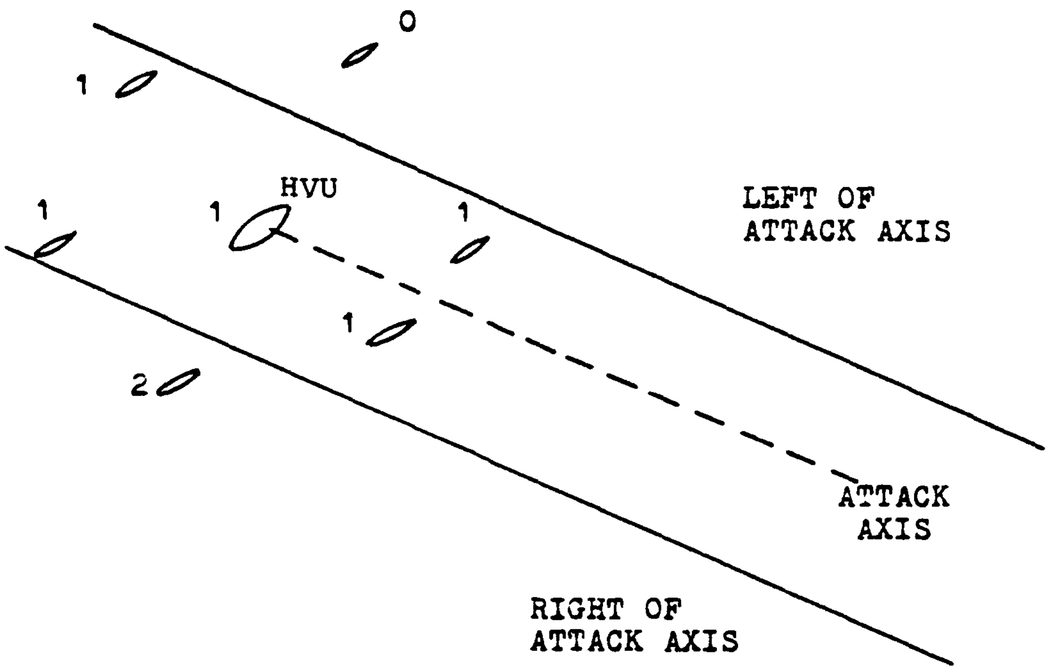


Fig. 2. Coding of the Plane Occupied by Ships in the Formation Relative to the Attack Axis.

This procedure of reducing the air defense of a formation into a one-dimensional problem is computationally attractive; however, the question remains as to what is lost from the simulation. In situations where the missile is detectable and intercepted at great ranges, very little is lost. For example, the usual U.S. battle group screen distance from the CV is 5 nm; intermediate range SAMs can intercept at 25 nm or more. At these ranges linearizing the problem had little impact on the results.

However, the maximum detection range of sea-skimming ASCMs is on the order of 15-22 nm, and first SAM intercept optimistically at 7-11 nm. A ship firing across one plane for an intercept at 5 nm will, in the LASMADS simulation, effectively receives an unwanted, artificial "bonus" of about 40% in effective SAM relative velocity due to the suppression of the off-axis geometric effects. This effect will be evident at intercept ranges less than 10 miles, but is insignificant beyond that. This will lead to more intercepts in the LASMADS simulation than would be actually possible. It should be noted that this effect is only present for engagements which involve ships and targets on different planes; since most of the ships will be considered to be on the axis, and most of the ASCMs targeted against them, this calculational error is not present for the majority of the engagements. However, as discussed in the

body of the paper, the change in number of possible intercepts is quantifiable and can be compensated for in the final result.

A further improvement to the LASMADS program would be to allow missile ships to only engage sea-skimming missiles which are on the same plane as the defending ship.

2. Time Intervals Between ASCM (TIMINT)

The LASMADS simulation models the incoming ASCM attack as a stream of missiles arriving with a constant interval between missiles. This is considered to be a reasonable model of ship-launched attacks, and serviceable when considering air-launched ASCM. The advantage of this formulation is that it is an easily-quantifiable variable, easily understood and translatable in terms of equipment capabilities. This is particularly important because of the very strong dependence of defending ship performance on TIMINT.

3. Coordination of SAM Area Defenses

Area defense missile systems are considered to be perfectly coordinated in the LASMADS simulation. Fire control channels are ordered by maximum to minimum reach along the range axis. When an ASCM penetrates the envelope, the first available fire control is assigned to engage. The missile is engaged by only that fire control--there is no possibility of an additional fire control simultaneously engaging the ASCM. When an ASCM is destroyed and the fire

control engaging it becomes available, it will be assigned automatically to the closest unengaged ASCM within its envelope.

The result is a simulation which will result in the best possible performance by the defending forces.

There is an additional benefit gained in the model by this formulation of the assignment of defensive assets and the stream nature of the attack. In most next-event type simulations, the dimension which the simulation moves along is time. The time of every event is stored in the computer. When that time is reached, the computer then must evaluate that event to decide if action is required or allowed. As a result, many events are "null" events which are evaluated as having no effect on the engagement.

For example, in a next-event type simulation when an ASCM enters each SAM envelope, the simulation must stop and evaluate that event for possible action. When the ASCM is already engaged, or the ship is destroyed, or all the ship's batteries already engaged, that event becomes a "null" event. The only thing affected is that additional computer time is required to evaluate the event.

In LASMADS, the dimension along which the simulation progresses is the next ASCM in the missile stream. The missile moves to an envelope, is engaged, and then moves directly to the intercept event. The missile is detected,

a battery is assigned to engage, the intercept is evaluated and re-engagement effected as necessary until the ASCM is engaged by point defense systems and hits the target. No extraneous event checks are required. During the flight time of the SAM, the ASCM might enter several envelopes; however, since the missile is already engaged, no event checks are required. Availability of fire control and self defense batteries are accounted for by simply recording the end time of engagement, and preventing the battery from engaging the next ASCM until that time is elapsed.

There are two advantages to this formulation. First, there is a major reduction in the run time required for the simulation, estimated to be about 35%, since the null events need not be evaluated. Second, since the incoming missiles are evaluated sequentially, the hit percentage resulting from that missile number in the stream is also the marginal value of adding an additional missile to the attack. Consequentually, it is possible in this simulation to run one attack of, say, 210 incoming ASCM and know the marginal value of each of the missiles. This is a decided benefit both in computer run time and in conceptualizing the results.

4. Range of Detection

A cookie cutter detection model was used with the range of detection determined by the operator in the scenario setup. The range of detection is determined from each ship individually; consequently, if an incoming ASCM is detected

by the outermost ship, only that ship is considered to have the contact and only that ship can engage the missile.

Altitude of the missile is not specifically modeled in the simulation. The operator determines the range of detection of the ASCM by his calculations or data external to the program, based on equipment performance, radar cross section, environment, and ASCM altitude. He inputs this value as the radar range to be used in that scenario (the input variable RADAR).

The range of detection is uniform over all the ships. There is no allowance for different radar performance.

5. Area Defense SAM Firing Doctrine

The SAM firing doctrine for area defense was "shoot-look-shoot shoot." When the firing range was great enough that if the SAM missed, there would be another firing opportunity by the same ship, then only one round was fired. If the range was so short that only one firing opportunity remained, then two rounds were fired. In the two round salvo, the possibility of success by each of the missiles was considered to be independent.

This firing doctrine was selected as a compromise between the demands of a high kill percentage for self-defense and the requirement to conserve limited amounts of ammunition. The optimality of this doctrine is discussed later in the paper.

The simulation does not allow chasing shots. A minimum SAM intercept range is specified for area defense weapons and firing is not allowed if the intercept point would occur at a range less than that specified minimum.

6. Point Defenses

There are four different types of point defense systems incorporated into the simulation:

PD SAM - Point defense surface-to-air missile, similar to NATO sea sparrow, BPDMS, or SAN-4.

MC GUN - Medium caliper gun systems, similar to 5" to 76mm.

CIWS - Close in weapon systems, similar to the Phalanx or the Soviet 30mm gatling system.

ECM - Electronic countermeasures, a combination of close-in chaff, deceptive repeating (RGPO) and jamming.

A single P-K is input by the operator for the kill probability of that class of weapons vs the incoming ASCM class. No distinction is made between different marks or mods of systems or different effectivenesses of systems within a class--for instance, the 5" gun will have the same kill probability as the 76mm.

Every missile is considered to have been detected in time to be engaged by the full range of point defense systems

on the target ship. However, the point defenses of a ship are not allowed to engage missiles which are targeted at a different ship.

All ships are considered to be on such a course as to allow the largest number of point defense systems on the target ship to engage. The duration of the attack is assumed to be so short that the ship does not have sufficient time to turn to present other batteries in the event that some of the defenses are destroyed or completely expend their ammunition.

The point defense routine in the program is called ENDGAME. It sequences the batteries to engage incoming missiles in the order of the range of the system with longest range systems engaging first. The first system to engage is PD SAM, followed by MC GUN, CIWS, and ECM. Times of engagement and cycles times between engagement are accounted for, preventing one battery from engaging two ASCM simultaneously. If there are two of a type of battery available, only one battery will be allowed to engage an individual ASCM.

ECM is considered to be last in the engagement queue, even though its range of engagement exceeds the range of other systems. The rationale is that an ECM "kill" does not involve the physical destruction of the incoming missile but rather its misdirection. It is assumed that this misdirection is so small that the other point defense systems would still be cued to engage the missile.

The cycle time between engagements is an input variable and is the same for each class of system. For ECM, a system time for a typical RGPO cycle is used. The assumption is that the ECM will only be able to engage one seeker at a time. However, by the queueing process in the program, that cycle will not be started on missiles which are destroyed by another AD or PD system. In the case of incoming COSRO (COnical Scan Range Only) seekers where many missiles can be engaged simultaneously by the ECM, a COSRO option is provided in the set-up. Essentially, this option sets the cycle time of the ECM to 0.0.

In addition, the ECM system is assigned a P-K, like any hard kill system. This is a bit questionable since usually the seeker is susceptible to electronic countermeasures or it is not, with no middle ground such as is usually represented by a probability. Thus, the system used in the program is a rough model and open to improvement.

7. Damage Assessment

The object of the damage assessment portion of the program was to provide real-time degradation of the defensive capabilities of a ship subject to battle damage. Consequently, the program concentrates on weapon systems, weapons controls and magazines, and does not address propulsion or seaworthiness.

A basic assumption made is that area defense SAM systems are sufficiently isolated from one another that a

cruise missile will only destroy one installation per hit, regardless of the weight of warhead and residual fuel. It is also assumed that the warhead will be large enough to eliminate the entire system if it hits in that part of the ship. There is no allowance for systems which may be degraded, but still capable of performing some functions. Point defense systems are treated probabilistically in that each missile hit has a 33% (20% in CVs) of destroying each point defense system.

Each penetrating missile is assigned a probability of hitting a part of the ship, as follows:

* There is a 5% chance of inflicting no area defense SAM system damage.
* There is a 15% chance of disabling all systems (CIC or catastrophic hit).
* There is a 40% chance of hitting the forward area defense installation.
* There is a 40% chance of hitting the after area defense installation.

In any case, the entire ship is considered to be out of commission on the third hit and all systems destroyed with the exception of U.S. aircraft carriers.

No attempt is made to tailor the damage to the resistance of the individual ships; a Kirov will be placed out of commission after the same number of hits as a Knox class frigate. This is an obvious area for improvement.

C. SETUP AND USE OF LASMADS

In the LASMADS simulation all the parameter changes, ship positioning and other adjustments are made in a designated section in the program. The program is then compiled and run.

For the IBM 3033 at the Naval Postgraduate School the set-up commands for the workspace are:

```
DEFINE STORAGE 1M
I CMS
GLOBAL TXTLIB FORTMOD2 MOD2EEH IMSLSP NONIMSL
FILEDEF 06 (followed by either printer or disk
designation)
```

The program listing included in this paper runs to approximately 2500 lines. However, this is deceptively large. A large number of the program lines are comments, included for clarity. Approximately 1100 of the lines are individualized ship initialization section. Since most of that work is repetitive, it could be compressed into a subroutine; however, it was not in order to allow clarity, to simplify the debugging procedure, and to allow easy adjustments of the capabilities of the ships. The actual working portion of the program, exclusive of input, is approximately 700 lines. Consequently, it is probable that the program could be run on a microcomputer.

Running time for a single iteration of a large attack on a battle group runs in under one second and, thus,

LASMADS itself might be a candidate for combat resolution for large, global wargames.

The only library subroutine used is LRND, a routine for generating uniform random numbers. It is used in the subroutine ROLL.

Lines 225-231 of the program listing permit using up to three loops in the program. The loop integer variables available are AA, TT, and SS. The loop statement numbers are 5, 6, and 7. The bottom of the loops are lines 2478-80. The purpose of these loops are to allow sequential tests, varying up to three variables. For example, the same battle group can be tested with varying TIMINT, radar range and/or composition of attack. When not used, these steps are commented out of the program. In various places, examples have been left in the program listing showing this technique (see lines 299, 308, 360).

Line 280 commences the normal operator input section to tailor the individual scenario.

Line 286 allows input of the number of repetitions of the scenario. Larger number of repetitions reduces the variance of the results. Two hundred repetitions was found to be sufficient when only one ship was defending; battle groups consisting of six or more ships should use over 500.

Line 289 requires the identification of the nationality of the defending ships. At this time, the program only differentiates between US and Soviet ships. The only change

incorporated was in the SAM missile velocity (see line 468). However, this technique could be used to further tailor equipment capabilities and performance to national standards.

Line 293 requires the total number of ships and decoys used in the scenario. In this case, decoys are designated offboard mobile decoys deployed in advance of the attack. Chaff deployed by ships to counter individual ASCMs is not considered as a decoy in this application. The total number of ships and decoys allowed is 20; however, the only thing that limited this is the dimension statements on the data storage and so this could be easily expanded if desired.

Line 296 requires the total number of attacking ASCM. The maximum number allowed (again, a dimension statement limitation) is 210.

Line 302 requires the class of the incoming ASCM. The program incorporates three classes:

#1 is a mach 0.8 sea skimmer;

#2 is a mach 2.0 intermediate altitude missile;

#3 is a mach 3.5 high altitude missile.

Each of these classes have separate P-K parameters and cycle time responses of the defending systems programmed.

Line 306 requires the time interval between incoming ASCM. The program assumes the interval between each missile is the same. A negative number should not be input.

Line 312 allows use of a radar activation delay. If this option is chosen (by setting DELAY=1), the defending vessels radars will not be on when the attacking ASCM reach the outermost reach of the ships' radars. The radars will be activated at a time DT seconds later, where DT is an input parameter (line 316). This option simulates a formation which is electronically silent and only activates radar at some warning such as an ESM intercept of a seeker head activation. Note that the delay time DT is counted in seconds starting from the usual cookie-cutter range of intercept for the first missile in the attack queue. Also, if the missile is scheduled to impact on the target before radar turn-on, the missile will still be engaged by the point defenses of the target.

Line 319 allows use of an option which incorporates detection, assignment, and handoff time delays. The program normally assumes perfect command and control of these elements. When this option is invoked, at each detection, assignment, or handoff there is a probability (input at line 323) that the action will take more time than optimum; the additional time is determined by multiplying a uniform random number with the maximum delay time (input at line 326). While this option has been successfully run, it has not been thoroughly debugged in its present form.

Line 329 allows the option of a given percentage of ASCM (input at line 333) to entirely slip through the area defenses and go directly to engagement by the point defenses of the targeted ship.

Line 336 allows the attacker to engage in two waves. Each wave is separated by a time input on line 340. Regardless of the time of separation, all ships in the defending formation are still consdiered afloat for targeting by the second wave. The damage on area and self defense systems remains. The effect of the time separation between the waves is to allow the defending systems to complete previous engagements and to be prepared to engage the following ASCMs.

Line 343 allows an option where targeting of the ASCM is adjusted towards the higher value targets. The usual method of assigning missiles to targets in the simulation is probabilistically, with probability in direct proportion to the ship's radar cross section. Line 343 allows selection of an "augmentation option" by assigning AUG = 1.

When the augmentation option is selected, a percentage of the missiles (input on line 346, HVTPER) are retargeted to higher value targets. The value of a ship as a target is determined by the operator. The priority of targeting is assigned by the order in which it has been input on lines 369-90. The amount of augmentation is determined by multiplying a uniform random number times the maximum percentage

that the missile targeting may be augmented (input on line 349, HVTVUL).

For example, assume there is a 6 ship battle group. The operator assigns the most valuable target as Ship #1, the next valuable as #2, and so on. A ASCM, originally targeted against Ship #5, is allowed augmentation by the random draw. The maximum degree of augmentation (input by the operator) in this example is 0.50. So, a missile may change targeting by a maximum of (6 x .5) = 3 places up the queue. An additional random number is drawn to determine how much of this possible augmentation it may use. The random draw is a .33, so it is augmented (3 x .33) = 1 place up in the value queue; consequently, the target is shifted from #5 to #4.

This procedure allows great flexibility in creating targeting distributions. Table 1 demonstrates the results of exercising various combinations of parameters. In the example, there are five ships in the targeted group, each with the same radar cross section. The normal targeting of 100 ASCMs is shown in Case 1, i.e., a uniform distribution. Cases 2 through 7 show the effect of different values of HVTPER and HVTVUL. Note that the program truncates decimals, so that a move up the queue of 1.99 places results in a move of only 1 place up.

TABLE 1

DEMONSTRATION OF TARGET AUGMENTATION OPTION

CASE NUMBER

	1	2	3	4	5	6	7
HVTPER	0	.5	.5	.75	.75	1.0	1.0
HVTVUL	0	.5	1.0	.5	1.0	.5	1.0
SHIP 1	20.0	28.1	40.2	31.9	50.0	35.7	60.3
2	20.0	20.1	17.8	20.1	17.1	20.1	16.0
3	20.0	20.0	16.1	20.1	14.2	20.0	11.8
4	20.0	18.1	13.9	17.1	10.6	16.0	8.0
5	20.0	13.8	12.0	10.9	8.1	8.2	3.9

Distribution of Targeting

100 missiles against 5 targets (equal radar cross section)

500 replications

This procedure is a bit tortured and cannot be justified in terms of modeling the actual targeting process. However, models of the targeting process are not available on the unclassified level. Consequently, this model was developed with the object of providing the maximum amount of flexibility for the operator in generating targeting distributions. By adjusting the parameter values, almost any desired targeting distribution can be realized. In the lack of a realistic targeting model, the decision was to opt for the ability to replicate almost any targeting scheme.

Line 352 allows the choice of an option to allow the ECM equipment the capability of multiple simultaneous engagements. This option is invoked by setting COSRO equal to 1. Invoking this option results in setting the cycle time of ECM engagements to 0.0 seconds.

Line 358 requires the input of the maximum detection range of the ships' radar against the ASCM. The program uses a cookie-cutter detection model with detection at that range from the detecting platform. This is an operator decision and should account for the power of the radar, the environment, the cross-section of the ASCM, altitude, and other factors of importance. When using Class 1 ASCMs (sea skimmers), the maximum detection range should be set at under 22 nm.

Line 366 requires the input of the required tracking time of the target until the ship can hand off the target to the

fire control systems. This tracking time is the same for all ships.

Lines 368 through 442 require the input of the ship class, position of the ship on the range axis, and whether the ship is located at the left, right, or center plane of the attack axis. The center plane will usually be referred to as "on" the attack axis.

The following ship classes are programmed:

#1 US Carrier

#2 CGN 38

#3 CG 26

#4 CG 16

#5 DDG 2

#6 DDG 37

#7 DD 963

#8 FFG 7

#9 FFG 1052

#10 TICONDEROGA (with VLS)

#11 KIROV

#12 KIROV (with UDALOY PD SAM)

#13 KIEV

#14 BLK COM 1

#15 SOVREMENNYY

#16 UDALOY

#17 MOSKOVA

#18 KARA

#19 KRESTA II

#20 KYNDA

#21 MOD KASHIN

#22 KRIVAK

#23 AUXILIARY

#24 CGN 36

#99 DECOY

Ships should be listed by their code number in order of value from high value to low. The value criteria is assigned by the operator and should be roughly the same as the targeting priorities of the attacking force.

The ships, in most cases, are considered to be with their planned weapons suites including, for many of the U.S. ships, CIWS and ECM systems which are scheduled for installation but not yet in place. The conspicuous exception is the DDG 2 class, which was retained with its current armament to check on the degradation of ship values for vessels with little point defense capability.

Table 2 is a listing of the weapons mounted on each ship class which can bear on the attack axis.

For the TICONDEROGA class, the vertical launch system is used. However, the full capabilities of the AEGIS system is not modeled for security reasons. Material published in open-source literature allowed the assignment of 18 fire

TABLE 2

WEAPONS SYSTEMS BEARING ON ATTACK AXIS

U.S. SHIPS

	CLASS #	#1 BATS	#2 BATS	#PD SAM	#MC GUN	#CIWS	#ECM
CV	1	0	0	2	0	2	1
CGN38	2	0	3	0	2	1	1
CG26	3	2	0	0	1	1	1
CG16	4	4	0	0	0	1	1
DDG2	5	0	2	0	2	0	0
DDG37	6	2	0	0	1	1	0
DD963	7	0	0	1	2	1	1
FFG7	8	0	1	0	1	1	1
FFG1052	9	0	0	1	1	0	1
CG47	10	0	18	0	2	1	1
CGN38	24	0	4	0	2	1	1

SOVIET SHIPS

KIROV	11	12	0	2	2	2	1
KIROV MOD	12	12	0	6	1	2	1
KIEV	13	0	2	1	2	2	1
BLK COM 1	14	6	0	2	1	1	1
SOVREM-ENNYY	15	0	3	0	2	1	1
UDALOY	16	0	0	2	2	1	1
MOSKOVA	17	0	2	2	1	0	1
KARA	18	0	1	1	1	1	1
KRESTA II	19	0	2	0	1	1	1
KYNDA	20	0	1	0	2	0	0
MOD KASHIN	21	0	1	0	2	0	0
KRIVAK	22	0	0	2	2	0	0

control channels as the capability of this system. Similarly, little is known about the capabilities of the TOP DOME systems installed on the KIROV and a follow-up cruiser class (BLK COM 1, an acronym for "Black Sea Combatant Ship Number 1" also identified in some U.S. sources as the KRASINA class). As a rough estimate, 6 channels per system were assigned as the capability of this system.

Assignment of the ship position on the range axis is performed as described above. All positions should be positive real numbers in nautical miles.

How far away from the direct line between the firing ship and the high value unit that a ship must be before it is considered to be on a different plane is dependent on the performance of the missile. If there is little degradation of the kill probability as the incidence angle increases, it is possible to move the criteria for an off-axis ship further out. This effect should be balanced against the geometric/relative velocity effects.

This criteria was not fully investigated in this study. As a approximation, a criteria of 2.5 nm off the axis of attack was used in the test program. Refining the result of the effect of firing on crossing targets is a place where the LASMADS simulation can be imrroved and is subject for further research.

Lines 464 through 504 contain the standard setup values used in the base case study. They may be changed by the operator if desired. They are placed last in the setup section since they probably will not be changed as often as the actual scenario composition. Values contained herein include:

* ASCM velocity (CMVEL for each class, CMVOL for the class used in the run);
* Surface to air missile velocity (SAMVOL);
* P-K for each weapon vs each missile type;
* Minimum and maximum intercept ranges for the long and intermediate range area defense SAMs;
* Cycle time for each weapon system (defined as that amount of time required from the end of one engagement to commence firing for the next);
* Kill assessment time (ASSES);
* Time between missiles in a two-SAM salvo (SALVO);
* Off-angle degradation as discussed above (OADES);
* Radar cross section of deployable decoys (DXCS).

D. SIMULATION OUTPUT AND DEMONSTRATION OF CAPABILITIES

1. Output Options and Description

Line 456 allows the user to specify the desired output. There are four output options currently programmed: #1 produces only a one-page summary of the engagement;

#2 produces the summary and a printout of the probability of hit of each missile, cumulative hits up to that missile, and percentage of hits through that missile;

#3 produces the summary, the missile data, and a plot of the percentage of hit for missiles 1 through 120;

#4 generates only the capacity and collapse values.

Tables 3, 4, 5, 6, 7, 8 and 9, and Figures 3, 4 and 5 are demonstrations of the capability and output of the LASMADS simulation.

Table 3 shows the basic output. Most of the entries are self-explanatory. All times are in seconds and all distances are in nautical miles.

In the "Result of the Engagement" section, all values are averaged over the number of replications to give expected value results.

In the "Average Total Ships OOC" line, a ship is considered out of commission (OOC) if it has sustained three or more ASCM hits, regardless of the actual damage caused by the hits.

"Area Def Rounds Destroyed" is calculated by summing the number of SAM missiles in magazines destroyed by missile hits, missiles on ships which have sustained a CIC hit and thus do not have the capability to fire the missiles, and missiles remaining on ships sustaining three or more ASCM hits.

TABLE 3

**** L.A.S.M.A.D.S. OUTPUT ****

ATTACK STATISTICS		DEFENSE STATISTICS	
NUMBER OF ATTACKING ASCM	24	NUMBER OF DEFENDING SHIPS	4
ASCM MISSILE CLASSIFICATION	2	NUMBER OF AREA DEF SHIPS	2
SECONDS BETWEEN MISSILES	10.0	NUMBER AREA DEFENSE BATTERIES	6
NUMBER OF WAVES	1	NUMBER SELF DEFENSE BATTERIES	16
HVT TARGETING	0	NUMBER AREA DEFENSE RNDS INIT	120
PERCENT HVU TARGETING	0.0	RADAR RANGE	180.0
AUGMENT PERCENTAGE	0.0	ECM CYCLE TIME	24.0

RESULT OF THE ENGAGEMENT OVER 5000 REPLICATIONS

		PERCENT
AVERAGE TOTAL HITS ON SHIPS	2.57	0.107
AVERAGE TOTAL SHIPS OOC	0.27	0.068
AREA DEF BATTERIES REMAINING	4.00	0.667
SELF DEF BATTERIES REMAINING	13.51	0.844
AREA DEF ROUNDS REMAINING	62.21	0.518
AREA DEF ROUNDS DESTROYED	26.69	0.222

INDIVIDUAL SHIP STATISTICS

NUMBER	CLASS	TYPE	POSITION	AXIS
1	24	2	20.00	1
2	5	2	15.10	0
3	7	0	15.12	2
4	7	0	11.00	1

SHIP	#1 BATS	#2 BATS	#PD SAM	#MC GUN	#CIWS	#ECM
1	0	4	0	2	1	1
2	0	2	0	2	0	0
3	0	0	1	2	1	1
4	0	0	1	2	1	1

SHIP	#TARGETED	#HITS	#KILLS	RNDS REM
1	6.11	0.62	13.63	44.62
2	4.41	1.44	3.51	17.58
3	6.73	0.30	2.26	0.0
4	6.75	0.21	2.02	0.0

SYSTEM PERFORMANCE OF INDIVIDUAL DEFENSES

	KILLS	RDS EXP	# SINGLE	# SALVO
LONG RANGE AIR DEFENSE SAM	0.0	0.0	0.0	0.0
INT RANGE AIR DEFENSE SAM	15.60	31.09	17.98	6.56
POINT DEFENSE SAM	2.81	3.74		
MEDIUM CALIFER GUN	0.49	4.96		
CIWS GUN	1.62	3.01		
ELECTRONIC COUNTERMEASURES	0.71	1.42		

TABLE 4

MISSILE REACHES SHIP TARGET- PERCENTAGE

ASCM	46	CUM HIT	CUM2	ASCM	46	CUM HIT	CUM2	ASCM	46	CUM HIT	CUM2
1	0.008	0.01	0.008	71	0.0	0.0	0.0	141	0.0	0.0	0.0
2	0.003	0.02	0.008	72	0.0	0.0	0.0	142	0.0	0.0	0.0
3	0.006	0.02	0.007	73	0.0	0.0	0.0	143	0.0	0.0	0.0
4	0.004	0.03	0.006	74	0.0	0.0	0.0	144	0.0	0.0	0.0
5	0.005	0.04	0.007	75	0.0	0.0	0.0	145	0.0	0.0	0.0
6	0.005	0.04	0.007	76	0.0	0.0	0.0	146	0.0	0.0	0.0
7	0.017	0.05	0.006	77	0.0	0.0	0.0	147	0.0	0.0	0.0
8	0.150	0.22	0.027	78	0.0	0.0	0.0	148	0.0	0.0	0.0
9	0.222	0.44	0.049	79	0.0	0.0	0.0	149	0.0	0.0	0.0
10	0.202	0.64	0.064	80	0.0	0.0	0.0	150	0.0	0.0	0.0
11	0.081	0.72	0.066	81	0.0	0.0	0.0	151	0.0	0.0	0.0
12	0.097	0.82	0.069	82	0.0	0.0	0.0	152	0.0	0.0	0.0
13	0.089	0.91	0.070	83	0.0	0.0	0.0	153	0.0	0.0	0.0
14	0.141	1.05	0.075	84	0.0	0.0	0.0	154	0.0	0.0	0.0
15	0.119	1.17	0.078	85	0.0	0.0	0.0	155	0.0	0.0	0.0
16	0.123	1.29	0.080	86	0.0	0.0	0.0	156	0.0	0.0	0.0
17	0.115	1.40	0.082	87	0.0	0.0	0.0	157	0.0	0.0	0.0
18	0.136	1.53	0.085	88	0.0	0.0	0.0	158	0.0	0.0	0.0
19	0.193	1.72	0.090	89	0.0	0.0	0.0	159	0.0	0.0	0.0
20	0.145	1.87	0.093	90	0.0	0.0	0.0	160	0.0	0.0	0.0
21	0.160	2.03	0.097	91	0.0	0.0	0.0	161	0.0	0.0	0.0
22	0.114	2.14	0.097	92	0.0	0.0	0.0	162	0.0	0.0	0.0
23	0.215	2.36	0.102	93	0.0	0.0	0.0	163	0.0	0.0	0.0
24	0.213	2.57	0.107	94	0.0	0.0	0.0	164	0.0	0.0	0.0
25	0.0	0.0	0.0	95	0.0	0.0	0.0	165	0.0	0.0	0.0
26	0.0	0.0	0.0	96	0.0	0.0	0.0	166	0.0	0.0	0.0
27	0.0	0.0	0.0	97	0.0	0.0	0.0	167	0.0	0.0	0.0
28	0.0	0.0	0.0	98	0.0	0.0	0.0	168	0.0	0.0	0.0
29	0.0	0.0	0.0	99	0.0	0.0	0.0	169	0.0	0.0	0.0
30	0.0	0.0	0.0	100	0.0	0.0	0.0	170	0.0	0.0	0.0
31	0.0	0.0	0.0	101	0.0	0.0	0.0	171	0.0	0.0	0.0
32	0.0	0.0	0.0	102	0.0	0.0	0.0	172	0.0	0.0	0.0
33	0.0	0.0	0.0	103	0.0	0.0	0.0	173	0.0	0.0	0.0
34	0.0	0.0	0.0	104	0.0	0.0	0.0	174	0.0	0.0	0.0
35	0.0	0.0	0.0	105	0.0	0.0	0.0	175	0.0	0.0	0.0
36	0.0	0.0	0.0	106	0.0	0.0	0.0	176	0.0	0.0	0.0
37	0.0	0.0	0.0	107	0.0	0.0	0.0	177	0.0	0.0	0.0
38	0.0	0.0	0.0	108	0.0	0.0	0.0	178	0.0	0.0	0.0
39	0.0	0.0	0.0	109	0.0	0.0	0.0	179	0.0	0.0	0.0
40	0.0	0.0	0.0	110	0.0	0.0	0.0	180	0.0	0.0	0.0
41	0.0	0.0	0.0	111	0.0	0.0	0.0	181	0.0	0.0	0.0
42	0.0	0.0	0.0	112	0.0	0.0	0.0	182	0.0	0.0	0.0
43	0.0	0.0	0.0	113	0.0	0.0	0.0	183	0.0	0.0	0.0
44	0.0	0.0	0.0	114	0.0	0.0	0.0	184	0.0	0.0	0.0
45	0.0	0.0	0.0	115	0.0	0.0	0.0	185	0.0	0.0	0.0
46	0.0	0.0	0.0	116	0.0	0.0	0.0	186	0.0	0.0	0.0
47	0.0	0.0	0.0	117	0.0	0.0	0.0	187	0.0	0.0	0.0
48	0.0	0.0	0.0	118	0.0	0.0	0.0	188	0.0	0.0	0.0
49	0.0	0.0	0.0	119	0.0	0.0	0.0	189	0.0	0.0	0.0
50	0.0	0.0	0.0	120	0.0	0.0	0.0	190	0.0	0.0	0.0
51	0.0	0.0	0.0	121	0.0	0.0	0.0	191	0.0	0.0	0.0
52	0.0	0.0	0.0	122	0.0	0.0	0.0	192	0.0	0.0	0.0
53	0.0	0.0	0.0	123	0.0	0.0	0.0	193	0.0	0.0	0.0
54	0.0	0.0	0.0	124	0.0	0.0	0.0	194	0.0	0.0	0.0
55	0.0	0.0	0.0	125	0.0	0.0	0.0	195	0.0	0.0	0.0
56	0.0	0.0	0.0	126	0.0	0.0	0.0	196	0.0	0.0	0.0
57	0.0	0.0	0.0	127	0.0	0.0	0.0	197	0.0	0.0	0.0
58	0.0	0.0	0.0	128	0.0	0.0	0.0	198	0.0	0.0	0.0
59	0.0	0.0	0.0	129	0.0	0.0	0.0	199	0.0	0.0	0.0
60	0.0	0.0	0.0	130	0.0	0.0	0.0	200	0.0	0.0	0.0
61	0.0	0.0	0.0	131	0.0	0.0	0.0	201	0.0	0.0	0.0
62	0.0	0.0	0.0	132	0.0	0.0	0.0	202	0.0	0.0	0.0
63	0.0	0.0	0.0	133	0.0	0.0	0.0	203	0.0	0.0	0.0
64	0.0	0.0	0.0	134	0.0	0.0	0.0	204	0.0	0.0	0.0
65	0.0	0.0	0.0	135	0.0	0.0	0.0	205	0.0	0.0	0.0
66	0.0	0.0	0.0	136	0.0	0.0	0.0	206	0.0	0.0	0.0
67	0.0	0.0	0.0	137	0.0	0.0	0.0	207	0.0	0.0	0.0
68	0.0	0.0	0.0	138	0.0	0.0	0.0	208	0.0	0.0	0.0
69	0.0	0.0	0.0	139	0.0	0.0	0.0	209	0.0	0.0	0.0
70	0.0	0.0	0.0	140	0.0	0.0	0.0	210	0.0	0.0	0.0

TABLE 5

**** L.A.S.M.A.D.S. OUTPUT ****

ATTACK STATISTICS		DEFENSE STATISTICS	
NUMBER OF ATTACKING ASCM	24	NUMBER OF DEFENDING SHIPS	4
ASCM MISSILE CLASSIFICATION	2	NUMBER OF AREA DEF SHIPS	2
SECONDS BETWEEN MISSILES	10.0	NUMBER AREA DEFENSE BATTERIES	6
NUMBER OF WAVES	2	NUMBER SELF DEFENSE BATTERIES	16
HVT TARGETING	0	NUMBER AREA DEFENSE RNDS INIT	120
PERCENT HVU TARGETING	0.0	RADAR RANGE	180.0
AUGMENT PERCENTAGE	0.0	ECM CYCLE TIME	24.0

RESULT OF THE ENGAGEMENT OVER 3000 REPLICATIONS

		PERCENT
AVERAGE TOTAL HITS ON SHIPS	2.14	0.089
AVERAGE TOTAL SHIPS OUT	0.21	0.052
AREA DEF BATTERIES REMAINING	4.31	0.718
SELF DEF BATTERIES REMAINING	13.91	0.870
AREA DEF ROUNDS REMAINING	64.16	0.535
AREA DEF ROUNDS DESTROYED	22.68	0.189

INDIVIDUAL SHIP STATISTICS

NUMBER	CLASS	TYPE	POSITION	AXIS
1	24	2	20.00	1
2	5	2	15.10	0
3	7	0	15.12	2
4	7	0	11.00	1

SHIP	#1 BATS	#2 BATS	#PD SAM	#MC GUN	#CIWS	#ECM
1	0	4	0	2	1	1
2	0	2	0	2	0	0
3	0	0	1	2	1	1
4	0	0	1	2	1	1

SHIP	#TARGETED	#HITS	#KILLS	RNDS REM
1	6.10	0.50	14.60	45.29
2	4.45	1.22	3.71	18.84
3	6.70	0.24	1.90	0.0
4	6.75	0.19	1.64	0.0

SYSTEM PERFORMANCE OF INDIVIDUAL DEFENSES

	KILLS	RDS EXP	# SINGLE	# SALVO
LONG RANGE AIR DEFENSE SAM	0.0	0.0	0.0	0.0
INT RANGE AIR DEFENSE SAM	17.05	33.15	20.33	6.41
POINT DEFENSE SAM	2.34	3.15		
MEDIUM CALIPER GUN	0.42	4.13		
CIWS GUN	1.47	2.47		
ELECTRONIC COUNTERMEASURES	0.58	1.17		

TABLE 6

**** L.A.S.M.A.D.S. OUTPUT ****

ATTACK STATISTICS		DEFENSE STATISTICS	
NUMBER OF ATTACKING ASCM	24	NUMBER OF DEFENDING SHIPS	4
ASCM MISSILE CLASSIFICATION	2	NUMBER OF AREA DEF SHIPS	2
SECONDS BETWEEN MISSILES	10.0	NUMBER AREA DEFENSE BATTERIES	6
NUMBER OF WAVES	2	NUMBER SELF DEFENSE BATTERIES	16
HVI TARGETING	0	NUMBER AREA DEFENSE RNDS INIT	120
PERCENT HVU TARGETING	0.0	RADAR RANGE	180.0
ADJMENT PERCENTAGE	0.0	ECM CYCLE TIME	24.0

RESULT OF THE ENGAGEMENT OVER 5000 REPLICATIONS

		PERCENT
AVERAGE TOTAL HITS ON SHIPS	2.00	0.064
AVERAGE TOTAL SHIPS LOC	0.18	0.044
AREA DEF BATTERIES REMAINING	4.38	0.731
SELF DEF BATTERIES REMAINING	13.99	0.875
AREA DEF ROUNDS REMAINING	65.25	0.544
AREA DEF ROUNDS DESTROYED	21.96	0.183

INDIVIDUAL SHIP STATISTICS

NUMBER	CLASS	TYPE	POSITION	AXIS
1	24	2	20.00	1
2	5	2	15.10	0
3	7	0	15.12	2
4	7	0	11.00	1

SHIP	#1 BATS	#2 BATS	#PD SAM	#MC GUN	#CIWS	#ECM
1	0	4	0	2	1	1
2	0	2	0	2	0	0
3	0	0	1	2	1	1
4	0	0	1	2	1	1

SHIP	#TARGETED	#HITS	#KILLS	RNDS REM
1	6.11	0.48	14.50	45.22
2	4.34	1.12	3.68	20.02
3	6.78	0.23	1.81	0.0
4	6.77	0.18	1.55	0.0

SYSTEM PERFORMANCE OF INDIVIDUAL DEFENSES

	KILLS	RDS EXP	# SINGLE	# SALVO
LONG RANGE AIR DEFENSE SAM	0.0	0.0	0.0	0.0
INT RANGE AIR DEFENSE SAM	17.39	32.78	20.77	6.01
POINT DEFENSE SAM	2.24	2.99		
MEDIUM CALIPER GUN	0.39	3.93		
CIWS GUN	1.42	2.38		
ELECTRONIC COUNTERMEASURES	0.56	1.14		

TABLE 7

**** L.A.S.M.A.D.S. OUTPUT ****

ATTACK STATISTICS		DEFENSE STATISTICS	
NUMBER OF ATTACKING ASCM	24	NUMBER OF DEFENDING SHIPS	4
ASCM MISSILE CLASSIFICATION	2	NUMBER OF AREA DEF SHIPS	2
SECONDS BETWEEN MISSILES	10.0	NUMBER AREA DEFENSE BATTERIES	6
NUMBER OF WAVES	2	NUMBER SELF DEFENSE BATTERIES	16
HVT TARGETING	1	NUMBER AREA DEFENSE RNDS INIT	120
PERCENT HVU TARGETING	0.70	RADAR RANGE	180.0
AUGMENT PERCENTAGE	0.70	ECM CYCLE TIME	24.0

RESULT OF THE ENGAGEMENT OVER 3000 REPLICATIONS

		PERCENT
AVERAGE TOTAL HITS ON SHIPS	2.87	0.120
AVERAGE TOTAL SHIPS COC	0.38	0.095
AREA DEF BATTERIES REMAINING	3.59	0.599
SELF DEF BATTERIES REMAINING	13.51	0.844
AREA DEF ROUNDS REMAINING	54.43	0.454
AREA DEF ROUNDS DESTROYED	32.99	0.275

INDIVIDUAL SHIP STATISTICS

NUMBER	CLASS	TYPE	POSITION	AXIS
1	24	2	20.00	1
2	5	2	15.10	0
3	7	0	15.12	2
4	7	0	11.00	1

SHIP	#1 BATS	#2 BATS	#PD SAM	#MC GUN	#CIWS	#ECM
1	0	4	0	2	1	1
2	0	2	0	2	0	0
3	0	0	1	2	1	1
4	0	0	1	2	1	1

SHIP	#TARGETED	#HITS	#KILLS	RNDS REM
1	9.44	1.01	14.71	38.58
2	5.49	1.60	3.75	15.83
3	5.39	0.18	1.66	0.0
4	3.68	0.08	0.57	0.0

SYSTEM PERFORMANCE OF INDIVIDUAL DEFENSES

	KILLS	RDS EXP	# SINGLE	# SALVO
LONG RANGE AIR DEFENSE SAM	0.0	0.0	0.0	0.0
INT RANGE AIR DEFENSE SAM	16.65	32.58	20.03	6.27
POINT DEFENSE SAM	1.79	2.41		
MEDIUM CALIPER GUN	0.49	4.63		
CIWS GUN	1.55	2.56		
ELECTRONIC COUNTERMEASURES	0.56	1.28		

TABLE 8

**** L.A.S.M.A.D.S. OUTPUT **** (Using penetration option)

ATTACK STATISTICS		DEFENSE STATISTICS	
NUMBER OF ATTACKING ASCM	24	NUMBER OF DEFENDING SHIPS	4
ASCM MISSILE CLASSIFICATION	2	NUMBER OF AREA DEF SHIPS	2
SECONDS BETWEEN MISSILES	11.0	NUMBER AREA DEFENSE BATTERIES	7
NUMBER OF WAVES	2	NUMBER SELF DEFENSE BATTERIES	18
HVT TARGETING	1	NUMBER AREA DEFENSE RNDS INIT	140
PERCENT HVU TARGETING	0.70	RADAR RANGE	180.0
AUGMENT PERCENTAGE	0.70	LCM CYCLE TIME	0.0

RESULT OF THE ENGAGEMENT OVER 2000 REPLICATIONS

		PERCENT
AVERAGE TOTAL HITS ON SHIPS	1.31	0.055
AVERAGE TOTAL SHIPS CDC	0.13	0.033
AREA DEF BATTERIES REMAINING	5.49	0.784
SELF DEF BATTERIES REMAINING	16.38	0.910
AREA DEF ROUNDS REMAINING	85.60	0.611
AREA DEF ROUNDS DESTROYED	21.33	0.152

INDIVIDUAL SHIP STATISTICS

NUMBER	CLASS	TYPE	POSITION	AXIS
1	24	2	20.00	1
2	2	2	15.10	0
3	7	0	15.12	2
4	7	0	11.00	1

SHIP	#1 BATS	#2 BATS	#PD SAM	#MC GUN	#CIWS	#ECM
1	0	4	0	2	1	1
2	0	3	0	2	1	1
3	0	0	1	2	1	1
4	0	0	1	2	1	1

SHIP	#TARGETED	#HITS	#KILLS	RNDS REM
1	9.69	0.74	13.73	44.49
2	6.44	0.44	0.58	41.07
3	4.68	0.09	1.24	0.0
4	3.20	0.04	0.73	0.0

SYSTEM PERFORMANCE OF INDIVIDUAL DEFENSES

	KILLS	RDS EXP	# SINGLE	# SALVO
LONG RANGE AIR DEFENSE SAM	0.0	0.0	0.0	0.0
INT RANGE AIR DEFENSE SAM	17.85	33.06	24.32	4.37
POINT DEFENSE SAM	1.45	1.92		
MEDIUM CALIPER GUN	0.44	4.24		
CIWS GUN	2.06	3.45		
ELECTRONIC COUNTERMEASURES	0.89	1.77		

TABLE 9

****** L.A.S.M.A.D.S. OUTPUT ******

ATTACK STATISTICS

NUMBER OF ATTACKING ASCM	24
ASCM MISSILE CLASSIFICATION	2
SECONDS BETWEEN MISSILES	10.0
NUMBER OF WAVES	2
HVT TARGETING	1
PERCENT HVU TARGETING	0.70
AUGMENT PERCENTAGE	0.70

DEFENSE STATISTICS

NUMBER OF DEFENDING SHIPS	4
NUMBER OF AREA DEF SHIPS	2
NUMBER AREA DEFENSE BATTERIES	6
NUMBER SELF DEFENSE BATTERIES	16
NUMBER AREA DEFENSE RNDS INIT	120
RADAR RANGE	180.0
ECM CYCLE TIME	0.0

RESULT OF THE ENGAGEMENT OVER 3000 REPLICATIONS

		PERCENT
AVERAGE TOTAL HITS ON SHIPS	4.11	0.171
AVERAGE TOTAL SHIPS LOC	0.63	0.156
AREA DEF BATTERIES REMAINING	2.94	0.489
SELF DEF BATTERIES REMAINING	12.62	0.789
AREA DEF ROUNDS REMAINING	47.53	0.396
AREA DEF ROUNDS DESTROYED	45.91	0.383

INDIVIDUAL SHIP STATISTICS

NUMBER	CLASS	TYPE	POSITION	AXIS
1	24	2	20.00	1
2	5	2	15.10	0
3	7	0	15.12	2
4	7	0	11.00	1

SHIP	#1 BATS	#2 BATS	#PD SAM	#MC GUN	#CIWS	#ECM
1	0	4	0	2	1	1
2	0	2	0	2	0	0
3	0	0	1	2	1	1
4	0	0	1	2	1	1

SHIP	#TARGETED	#HITS	#KILLS	RNDS REM
1	9.47	1.54	13.20	35.24
2	5.43	2.19	3.10	12.27
3	5.42	0.26	2.20	0.0
4	3.69	0.12	1.39	0.0

SYSTEM PERFORMANCE OF INDIVIDUAL DEFENSES

	KILLS	RDS EXP	# SINGLE	# SALVO
LONG RANGE AIR DEFENSE SAM	0.0	0.0	0.0	0.0
INT RANGE AIR DEFENSE SAM	13.77	26.56	18.33	4.11
POINT DEFENSE SAM	2.44	3.25		
MEDIUM CALIPER GUN	0.61	6.11		
CIWS GUN	2.01	3.39		
ELECTRONIC COUNTERMEASURES	1.05	2.14		

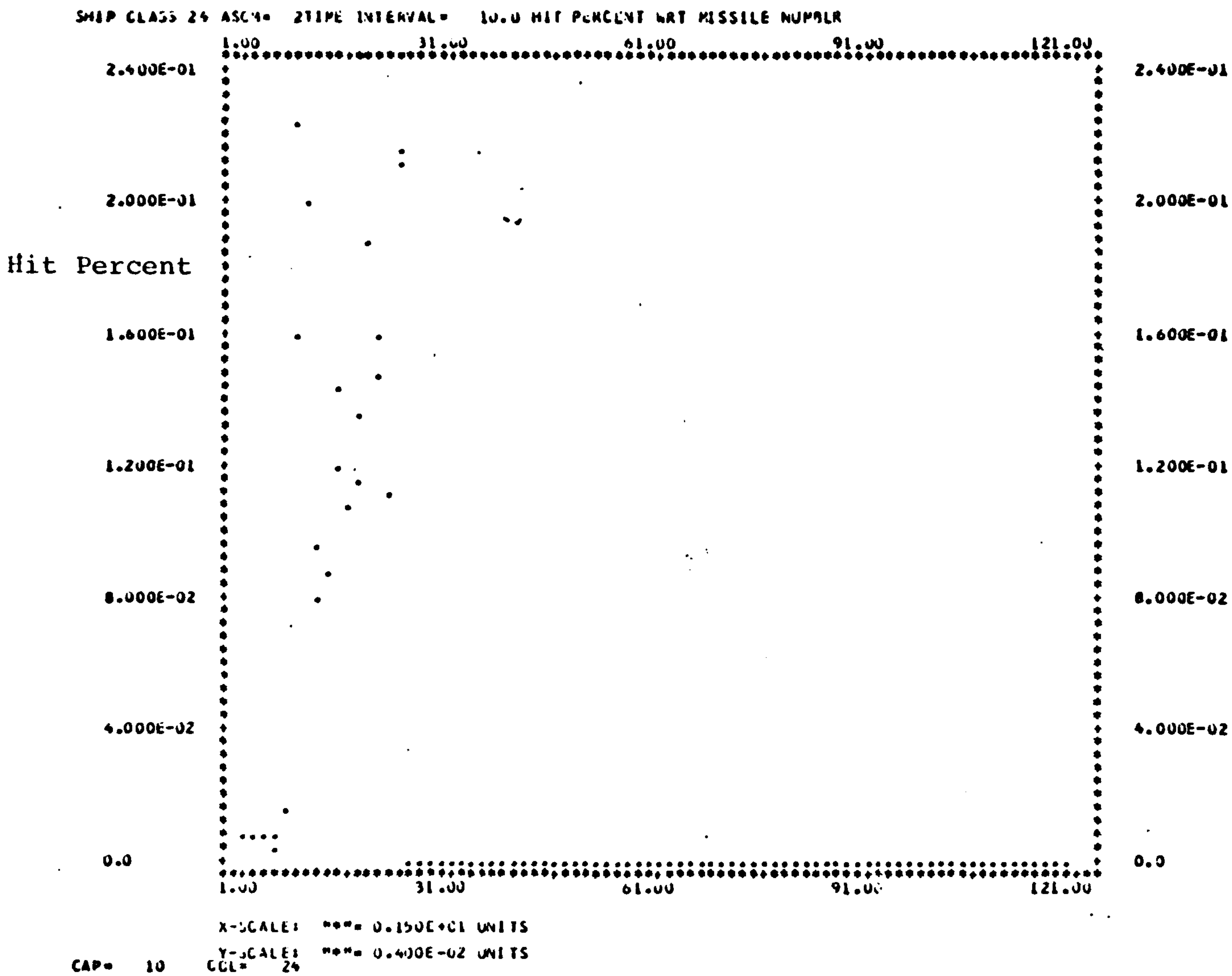


Fig. 3. ASCM Missile Number.

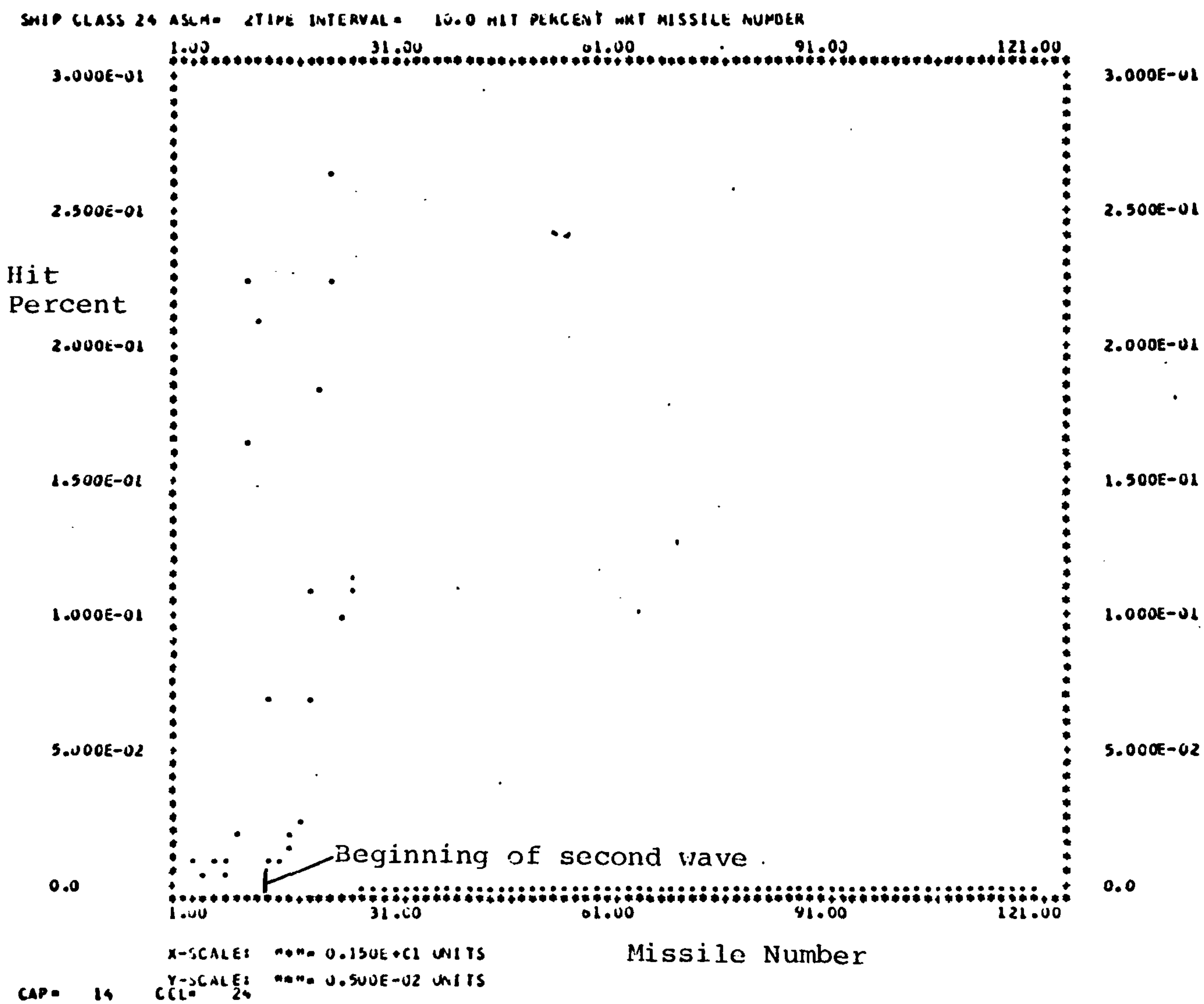


Fig. 4. Effect of Two Waves on Missile Hit Percentage

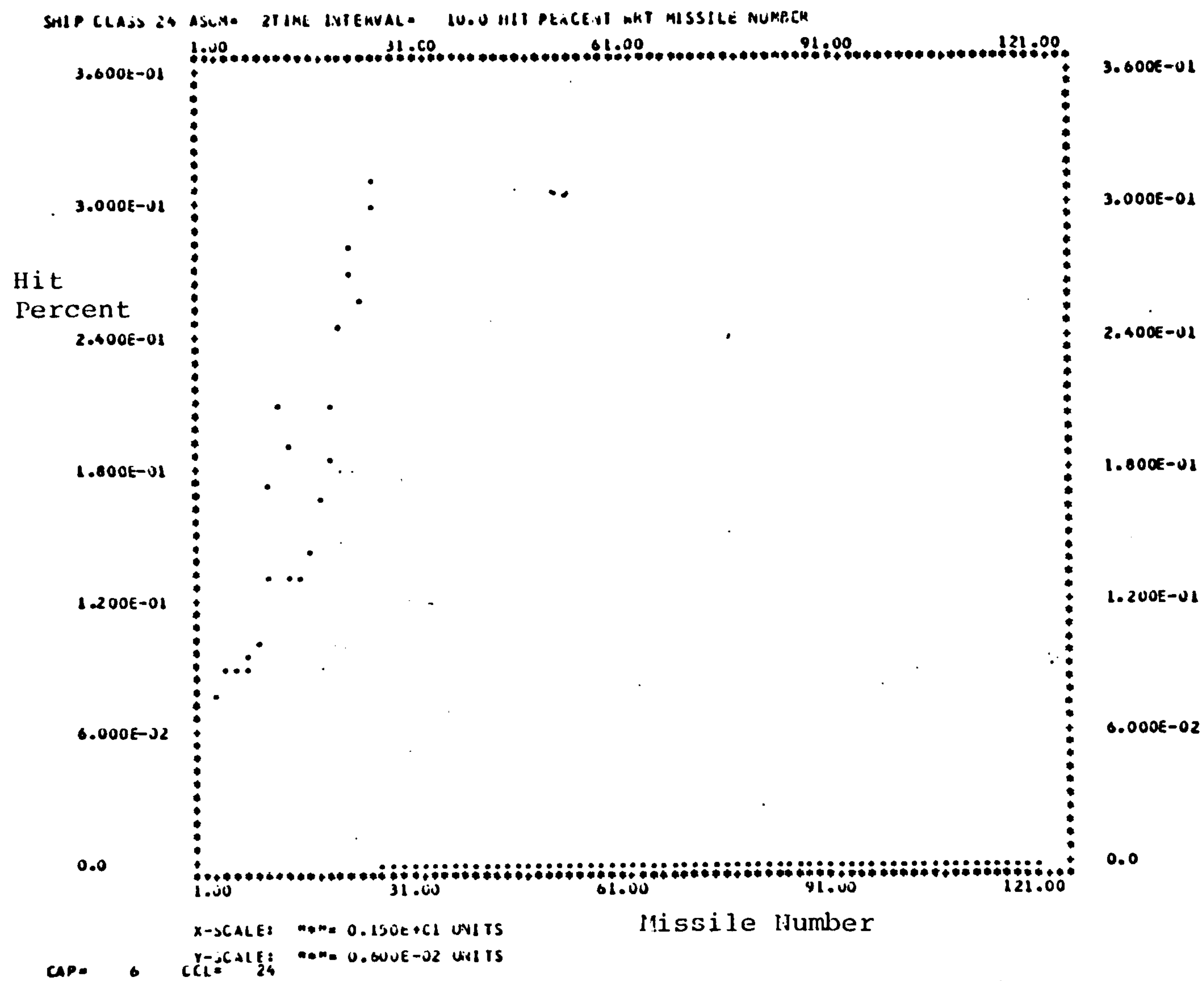


Fig. 5. Engagement Using Penetration Option

In the "individual ship statistics" section, "#1 BATS" are long range area defense SAM fire control channels and "#2 BATS" are the intermediate range area defense SAM fire control channels. "# TARGETED" is the average number of ASCMs targeted at that ship. "# HITS" is the average number of hits on that ship. "# KILLS" is the average number of ASCMs destroyed by that ship. "RNDS REM" is the average number of area defense SAM missile rounds remaining on that ship.

In "SYSTEM PERFORMANCE OF INDIVIDUAL DEFENSES," "KILLS" denotes the average number of ASCMs destroyed by that system; "RDS EXP" indicates the average number of engagements; "# SINGLE" and "# SALVO" records the number of single area defense SAMs fired and the number of salvos of area defense SAMs fired.

Table 4 shows in columnar format the average results attained by the individual ASCM. The first column ("ASCM") is the missile number. The second column (" %% ") is the average hit percentage of that missile. The third column ("CUM HIT") is the average cumulative number of hits achieved up to that missile number. The fourth column ("CUM %") is the cumulative percentage of hits up to that missile number.

This output has considerable value. Because of the construction of the simulation, the hit percentage of the missile is the marginal value of that missile, and the

cumulative hit column gives the expected number of hits on the targets for an attack consisting of that number of missiles.

2. Demonstration of Capabilities

As an example, a series of scenarios will be shown demonstrating the various options available to the operator.

Tables 3 and 4 and Figure 3 show the results of an attack by an OSCAR class submarine on a US SAG (Surface Action Group).

The SAG consists of four ships: a CALIFORNIA class CGN, an ADAMS class DDG, and two SPRUANCE class destroyers. The ships are in a circular formation approximately 10,000 yards from ZZ (formation center). ZZ is unoccupied. The two SAM ships have been placed closer to the missile threat area; the attack axis so developed that the CALIFORNIA and one of the SPRUANCEs were on the axis, while the ADAMS and the other SPRUANCE were respectively left and right of the axis.

In the engagement the OSCAR has fired 24 Class 2 (intermediate altitude, mach 2.0) ASCM at the formation. The missiles were separated by 10.0 seconds. Targeting was proportionate to ship's radar cross section.

Table 3 shows the overall results of the engagement. The CALIFORNIA class cruiser, which was on the attack axis closest to the origin of the attack and has the greatest anti-air capability, recorded the most ASCM kills. After

5000 runs, there were an average total of 2.57 hits on the ships, with an average of 0.27 ships placed out of commission. The ADAMS class DDG sustained the most hits because of its poor point defense capabilities and because it was on an attack plane of its own and thus the CGN's fire was not as effective in screening that ship. The fewest number of hits sustained was by ship #4, the SPRUANCE which was farthest from the origin of the attack and on the attack axis, and thus could be directly screened by the CALIFORNIA class. Between rounds fired and round destroyed in the magazines, the force only has approximately 50% of its area defense ammunition loadout remaining.

Table 4 shows the course of the attack from the attacker's viewpoint. Note the first 6 ASCM have a low probability of penetration; this is expected since the defending fource has 6 area defense batteries. Missiles 8, 9 and 10 have a significantly higher percentage of hit. Since they directly followed the first 6 rounds, they were unengaged during the period when the defending batteries were occupied with the first ASCMs in the stream and thus were allowed to penetrate the defensive zone and probably were engaged only by point defenses. The probability of hit for the next rounds are again lower, due to the area defense batteries being available to engage them. However, the percentage of hit was not as low as earlier since the

defending ships had by that time suffered battle damage and because the ASCM were closer to the formation and thus presented fewer intercept opportunities.

Figure 3 shows this in graphic output.

Table 5 shows the results of the same scenario with the modification that the OSCAR has fired its missiles in two waves, separated by 60.0 seconds. Note that the number of hits has been reduced to an average of 2.14. Table 6 is again the same situation, except the two wave attack is separated by 600.0 seconds. The number of hits has been reduced to an average of 2.00. This result is expected since the pause between waves allows the defending systems to complete their engagement cycle and prepare for the next wave. Figure 4 shows this effect graphically where the probability of hit of the missiles arriving first in the second wave is reduced to that of the first missiles in the first wave.

Table 7 shows the two wave attack with a 60.0 second wave separation but using the Augmented Targeting option. Seventy percent of the ASCM were allowed up to a 70% shift. Note the shift in the number of missiles targeted against each ship. Hits on the High Value Unit (HVU) has doubled from 0.50 to 1.01. Total hits on the formation has increased from 2.14 to 2.87 due to the damage sustained by the HVU and the resulting reduction of area defense capability.

Table 8 duplicates the scenario of Table 7 but using the COSRO ECM option which allows for multiple simultaneous ECM engagements (further discussion of this option follows in a later section). Total hits on the formation is reduced by over 50% to 1.31 hits. Note, however, that the actual number of kills attributed to ECM increases only a small amount, from 0.66 kills to 0.89 kills.

Since ECM is considered a kill only when the ASCM has penetrated all other defenses, the small increment in ECM kills is directly translatable into hits prevented. Hits prevented results in systems preserved from destruction. These systems are thus "alive" for a greater period and able to acquire, engage, and destroy additional targets. Consequently, there is an increased performance by other point and area defenses when the ECM system is given more capability. This explains why the ECM system accounted for an increase of 0.23 kills and the other systems accounted for the remaining increase of 1.33 kills over the number of kills recorded in Table 6. This example also illustrates the interactive nature of the various point and area defense systems to the total defensive capability of the vessel.

Table 9 is for the same scenario as in Table 8 with the inclusion of the area defense penetration option. Randomly, 25% of the attacking ASCM were allowed to slip through the area defenses without being engaged. Total hits on the ships has increased from 1.31 to 4.11. Figure 5

shows graphically the effect of this option on the hit percentage of the missiles in the stream.

The above section has demonstrated some of the options available in the LASMADS simulation. Other options (such as command and control degradation) are available and, obviously, the possible scenarios available to exercise every combination of option and parameters of each option are immense. The object of the research was to isolate and characterize the most important effects to achieve representative Firepower Indexes that characterize a ship's AAW capability.

III. FORMULATION OF AN INDICATOR OF SHIP COMBAT POWER

A. BASIC BEHAVIOR OF THE MARGINAL VALUES OF ADDITIONAL ASCM IN AN ATTACK

Figures 6 through 9 are examples of plots of hit percentage plotted against missile number. As discussed before, the nature of the LASMADS simulation equates the marginal value of adding an additional missile on to an attack to the hit percentage realized by that missile in a stream attack. The figures represent two classes of ships--KIROV, with a very large area and point defense anti-air capability, and KARA, with a relatively smaller capability--and two time intervals between incoming ASCM, 0.1 seconds and 1000.0 seconds.

All of the curves have similar features. These features are demonstrated on Figu-- 10.

For an initial number of missiles shown as "A" to "B" on the graph, there is a low and fairly constant hit percentage. This is representative of those intensities of attacks which are within the ability of the ship to handle. The resulting percentage of hits is the result of unsuccessful engagements by the defending systems.

Point "C" represents an inflection point where the slope of the hit probability turns sharply upwards. This point represents the intensity of attack which is near the limit of the defending systems' defensive capability.

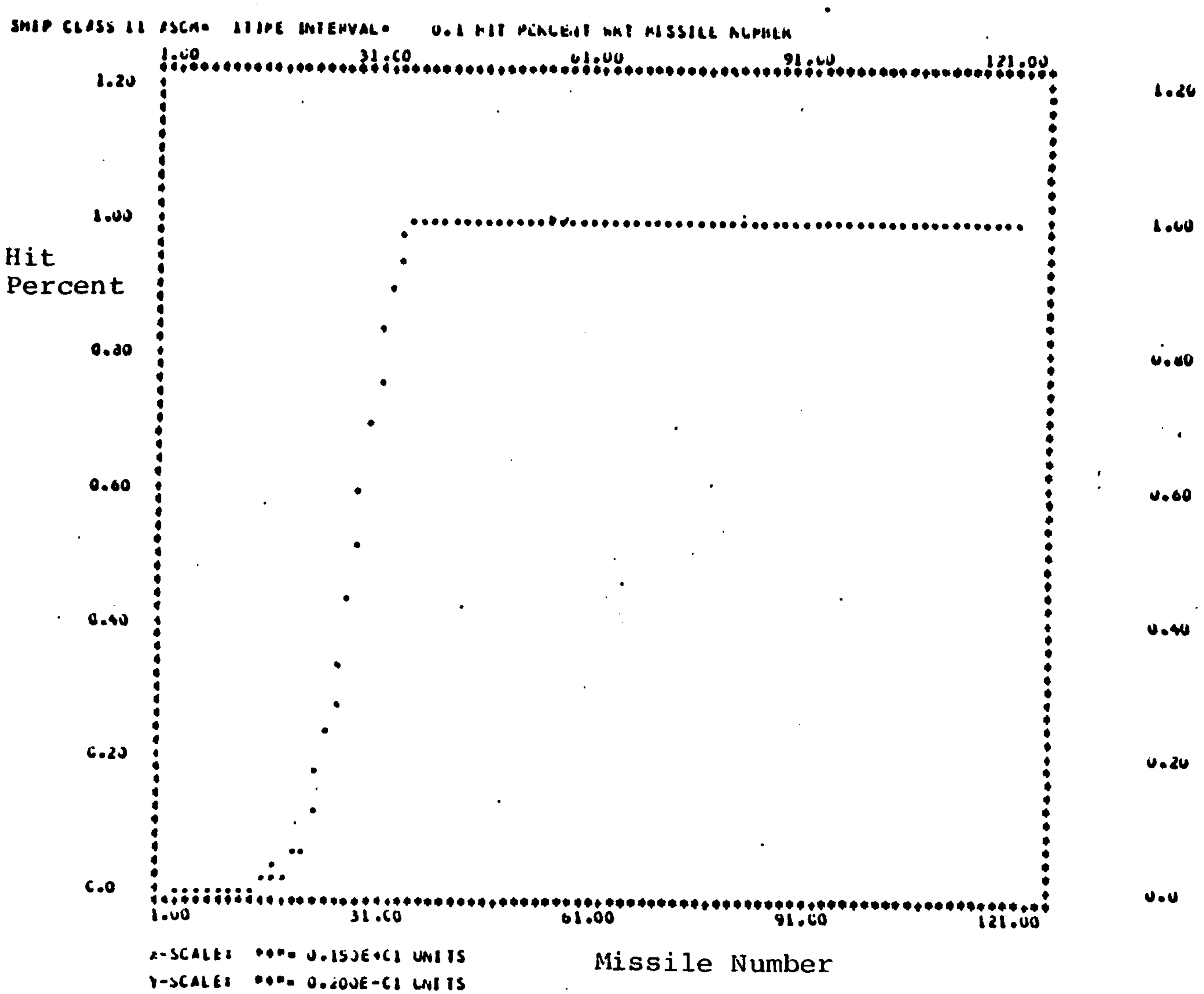


Fig. 6. KIROV Class 0.1 Second TIMINT.

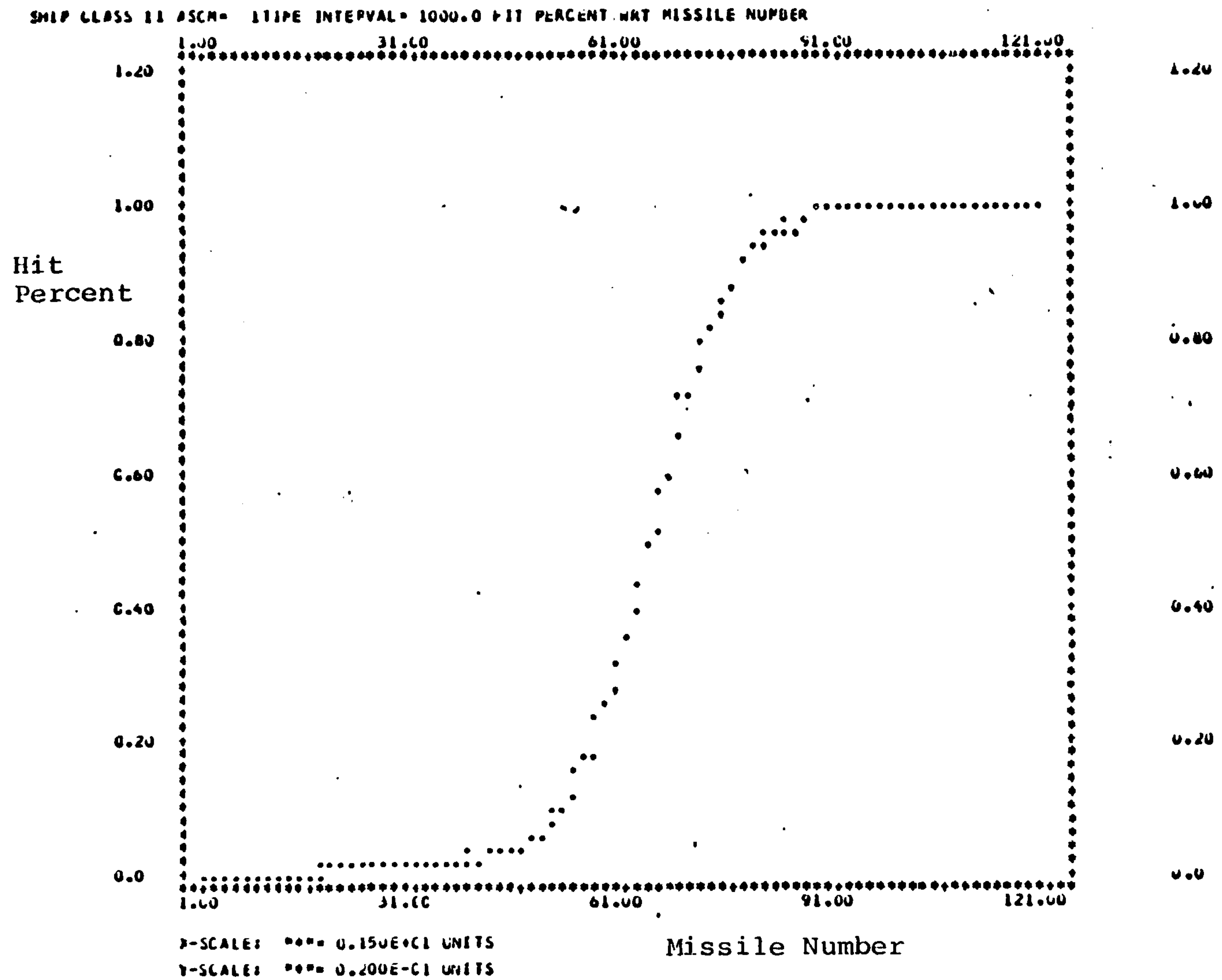


Fig. 7. KIROV Class, 1000 Second TIMINT.

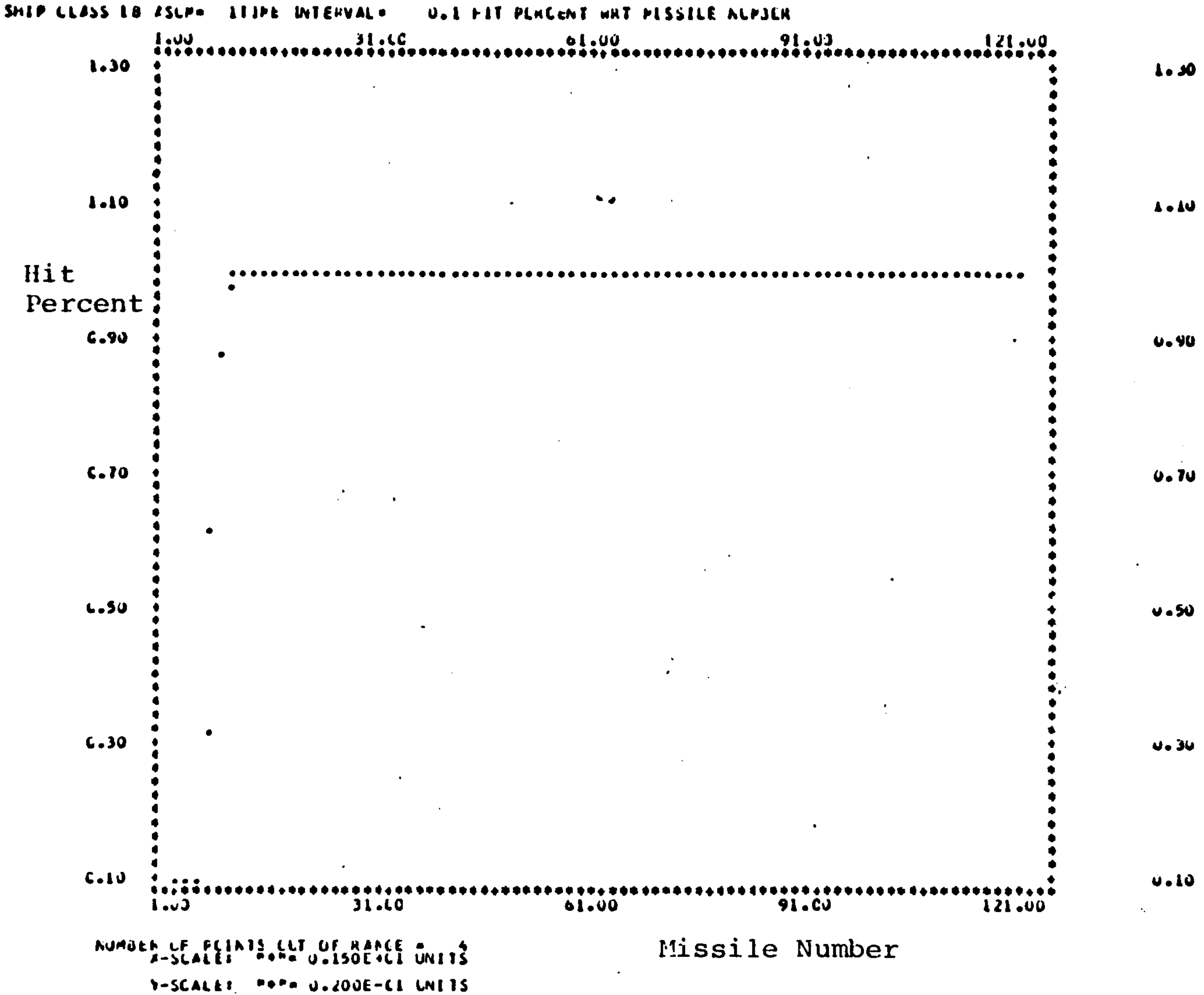


Fig. 8. KARA Class 0.1 Second TIMINT.

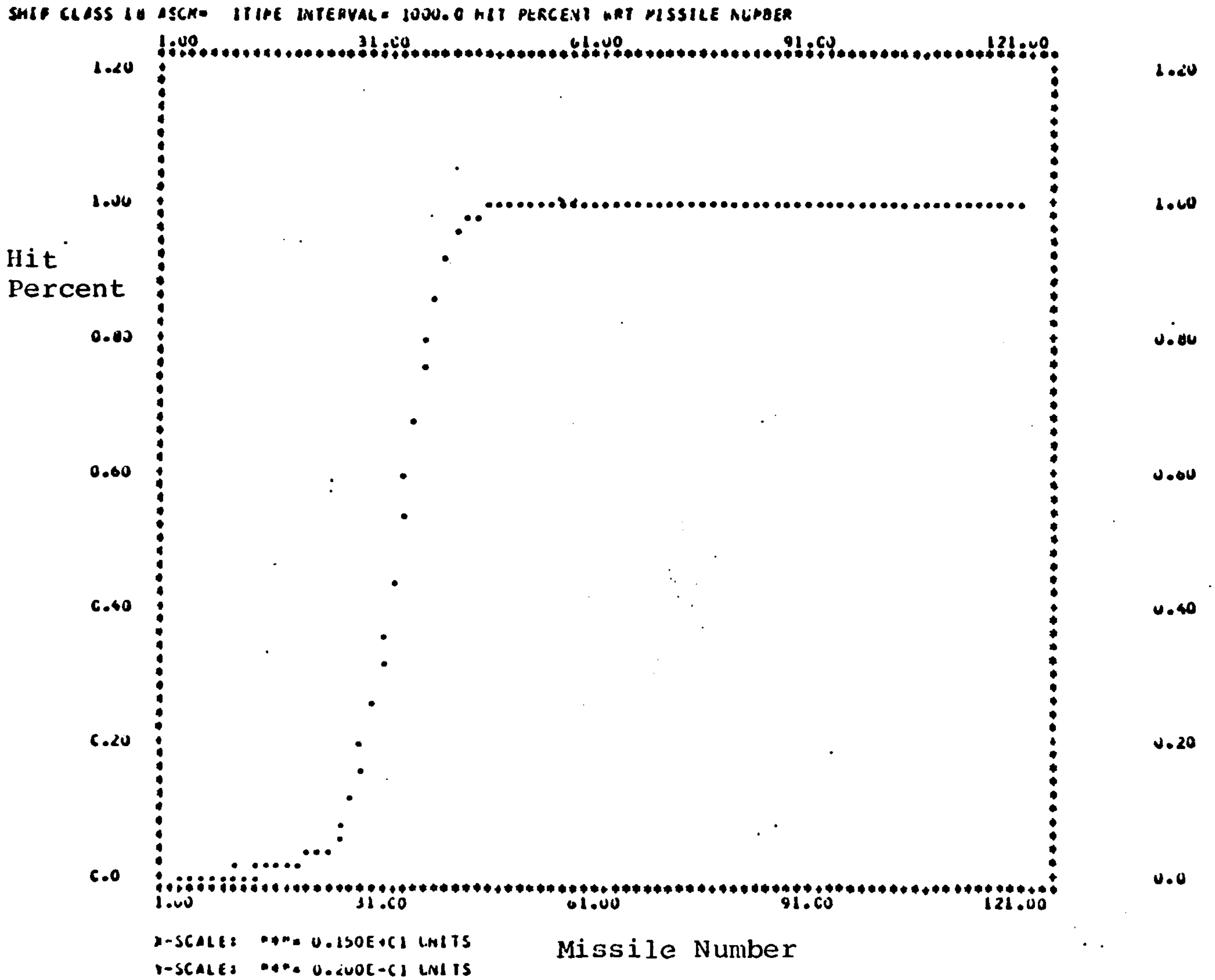


Fig. 9. KARA 1000 Second TIMINT.

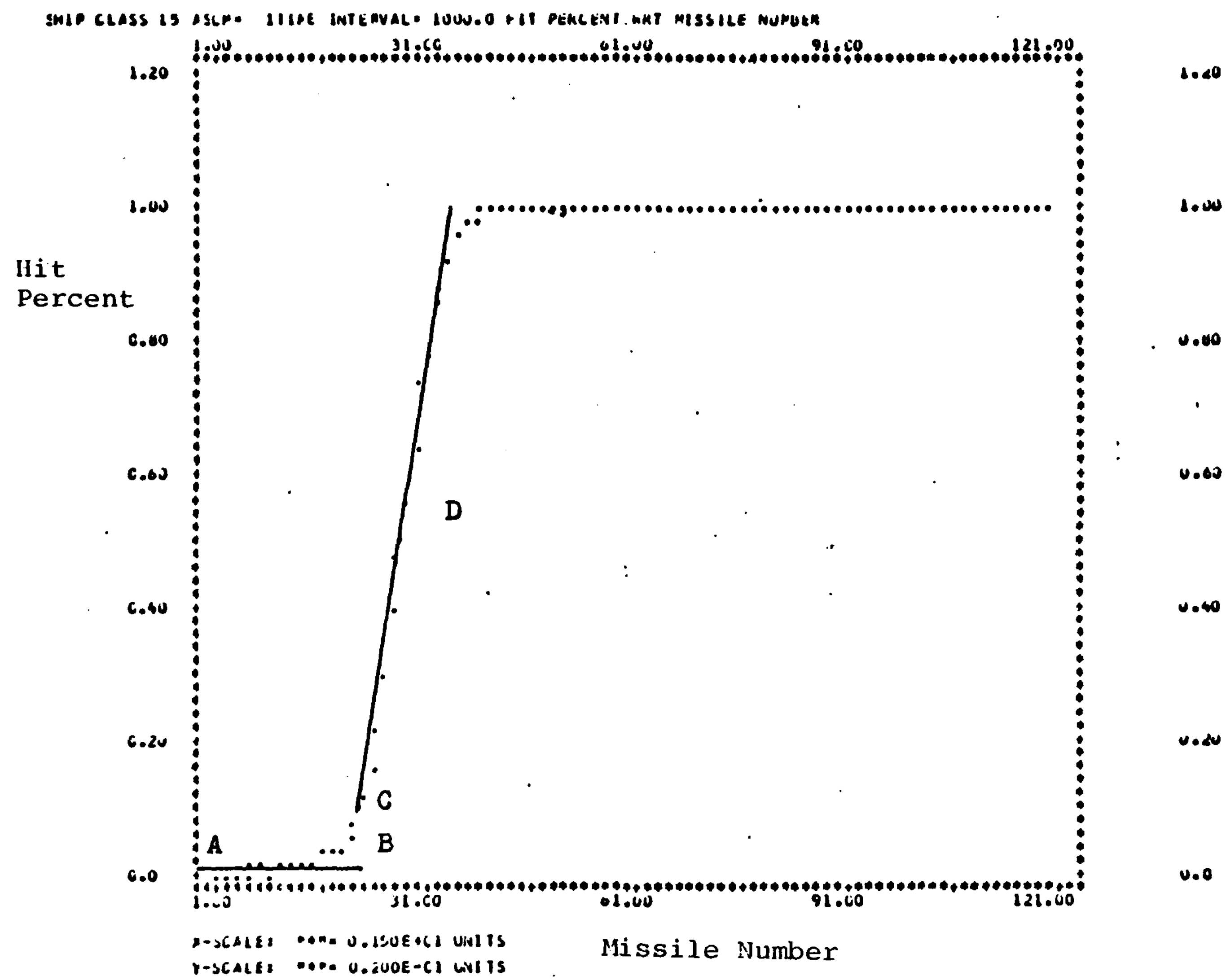


Fig. 10. Single Ship.

There are three factors which are responsible for the number of missiles defeated by the ship before the inflection point is reached: first, seen in the 0.1 second TIMINT plots, the number of incoming ASCM exceed the number of systems available to counter them; second, seen in the 1000.0 TIMINT plots, the cumulative damage inflicted by the ASCMs leaking through the defenses has inflicted sufficient damage on defending systems that the effectiveness of the successive layers of defense of the ship has been reduced; third, in the case where the defenses are particularly good, in the 1000.0 TIMINT case ammunition supply will limit the survival of the platform. For values of TIMINT between these two extremes, a combination of these effects is responsible for the upward turn in the probability of missile hit.

From point "C", the plot of hit percentage rises with nearly a constant slope. This slope is established by defining a point "D" which is defined as that point where the hit percentage of the ASCMs exceeds 50%. The slope remains constant until a point is reached where a tailing off is usually present. This tailing off usually starts at a percentage in the range of 85-90 percent.

This curve is characteristic of all of the probability of hit plots performed on all of the individual ships tested, regardless of number or composition of the various area and point defense installations. However, each vessel

had different values for the level between "A" and "B", the missile number of the inflection point "C", and the slope of the line between "C" and "D". When the conditions of the attack, or the capabilities of the defending systems were adjusted, the curve retained its general shape but had different values for the above points.

More significantly, this behavior was retained when dealing with formations of ships. For example, Figure 11 is a plot of the probability of kill vs missile number for a six-ship U.S. carrier battle group. Although the inflection point is more rounded, this curve still has the characteristic initial level, inflection point, and positive constant slope.

The following terms are used in describing the model:

The percentage of hits experienced between point "A" and "B" is called the LEAKAGE. It will be considered as a constant and is determined by using the average cumulative hit percentage at the inflection point "C".

The inflection point "C" is called the CAPACITY of the ship. By experimentation it was decided to fix this point at that missile number that exceeded a hit percentage of 10%.

With point "C" determined, the slope of line "C-D" can be defined by using one additional point. This point was fixed as the missile number where the probability of hit exceeded 50%. This point was defined as the COLLAPSE point.

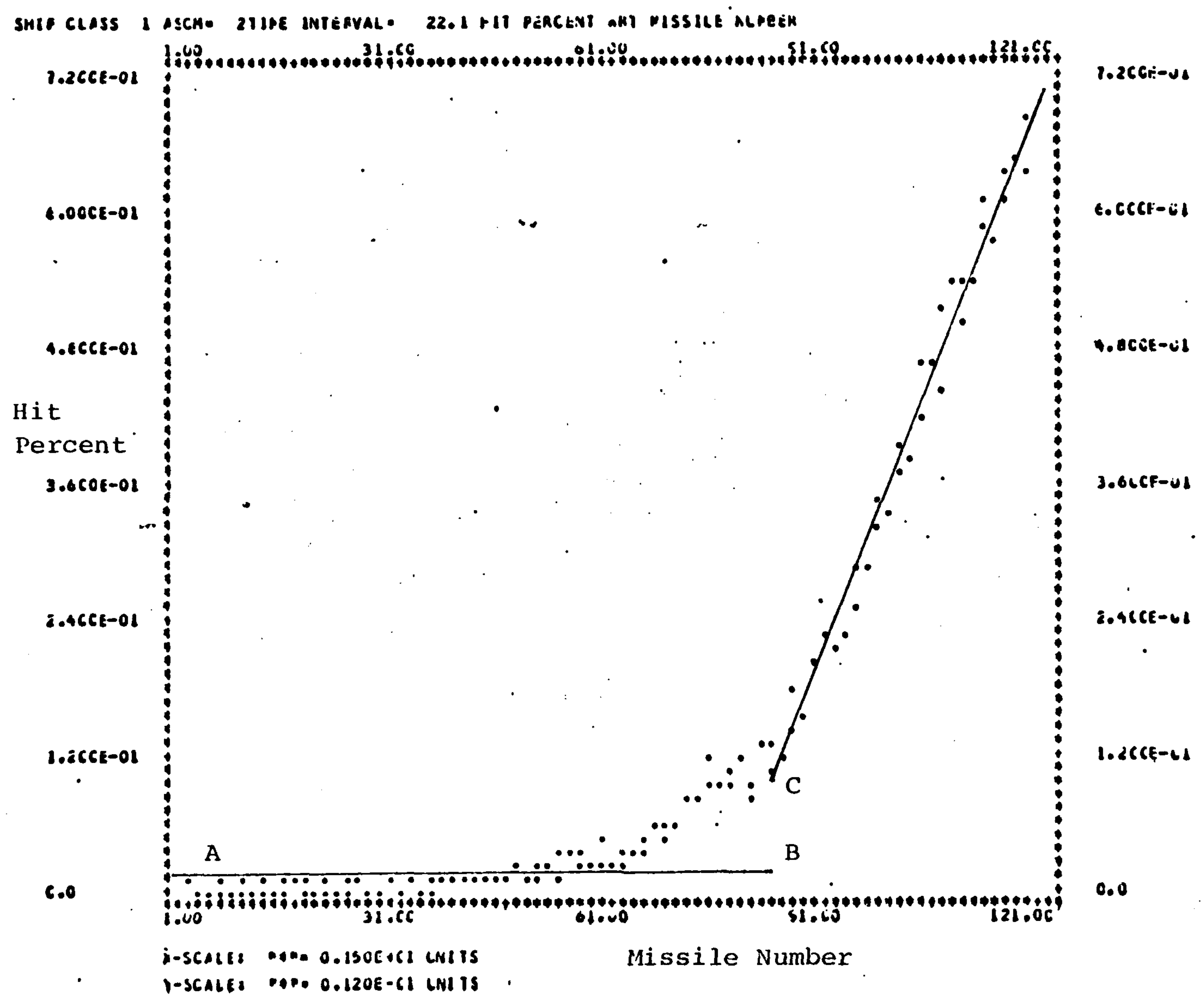


Fig. 11. Formation of Six Ships.

The model for a ship's AAW defense was thus defined by three values: a capacity value which determined the point where the ship's defenses could no longer fully defend itself against additional missiles; a leakage value, which was the percentage of hit for all missile attacks sized less than capacity; and a collapse value, which, with the capacity value, defined the rate of increase of the hit percentage for all missiles above a capacity attack.

It should be noted that there is a discontinuity in this model; at missile number (capacity-1), the hit percentage is equal to leakage. At missile number (capacity), the hit percentage is equal to 10%.

The curve described above is the basic model for the results of an ASCM attack on surface vessels. The next objective would be to determine which parameters were of first order significance and how exactly they affected the shape and placement of the values of the curve. In other words, the above is proposed as a fundamental model; the values in the model are determined for a base set of conditions; and those values are subsequently modified to account for variations from the base case.

B. DEFINITION OF THE BASE CASE SCENARIO

The general purpose of defining the base case is to provide a foundation for the model. The base case is generally defined as those sets of conditions which allow

the defending ships to reach their full defensive combat power. In realistic terms, this could be interpreted as a clear environment, maximum radar performance, warning of the attack, optimum command and control, full magazines, and an attacking ASCM which is within the capabilities of the defending systems. Given this situation, all adjustments to the basic values generated are degradations to ship performance.

In terms of the LASMADS model, the base case conditions are a range of detection of 180.0 nm, with a Class 2 (intermediate altitude, mach 2.0) incoming ASCM. None of the other options are used.

The Class 2 ASCM was chosen because it was considered the easiest to destroy: P-K values of 0.7 for area defense SAM, 0.75 for point defense missiles, 0.10 for medium caliber gun, 0.60 for CIWS, and 0.50 for ECM were used.

To determine baseline values, engagements were run on each of the ship classes in this study. Attacks consisting of Class 2 ASCMs in very large numbers were considered, and usually 1000 replications were run. For reasons discussed below, a run using TIMINT of 0.1 seconds, representing a near-perfectly coordinated time-on-target wave attack, and a run using a TIMINT of 1000.0, representing an uncoordinated stream attack were used. From these results the leakage, capacity, and collapse values were determined. Table 10 shows the results of these runs.

TABLE 10

SUMMARY TABLE OF RESULTS OF SHIP VALLATION

CLASS 1D NR	CLASS	LEAK	CAPACITY 0.1 - 1000	COLLAPSE 0.1 - 1000.0	TIMINT
1	CARRIER	.06	2 - 8	4 - 13	
2	CGN 38 VIRGINIA	.02	5 - 37	7 - 45	
3	CG 26	.02	4 - 27	6 - 32	
4	CG 16	.02	6 - 51	8 - 60	
5	DDG 2 ADAMS	.04	3 - 22	4 - 27	
6	DDG 37	.03	4 - 26	6 - 30	
7	DD 963 SPRUANCE	.06	1 - 4	3 - 7	
8	FFG 7 PERRY	.03	2 - 19	4 - 24	
9	FFG 1052 KNOX	.13	1 - 1	2 - 5	
10	CG 47 TICONDEROGA	.02	30 - 60	34 - 71	
11	KIROV	.01	31 - 71	34 - 85	
12	KIROV (MOD 1)	.01	33 - 74	38 - 94	
13	KIEV	.01	4 - 47	6 - 57	
14	BLK COM I	.01	16 - 48	18 - 62	
15	SOVREMENNYY	.02	5 - 25	6 - 31	
16	UDALOY	.07	2 - 6	3 - 20	
17	MUSKOVA	.02	4 - 28	6 - 39	
18	KARA	.02	4 - 31	6 - 38	
19	KRESTA II	.02	3 - 25	5 - 31	
20	KYNDA	.02	1 - 11	2 - 14	
21	MOD KASHIN	.02	3 - 25	5 - 31	
22	KRIVAK	.23	1 - 1	2 - 9	
23	AUXILIARY				
24	CGN 36 CALIFORNIA	.02	6 - 48	8 - 57	

C. MODIFICATION OF THE BASE CASE TO ACCOUNT FOR FIRST ORDER EFFECTS

1. Time Intervals Between Attacking ASCM

As discussed above, there are three factors which tend to limit the survival of a platform: capacity for handling simultaneous targets, cumulative damage due to leakage, and ammunition supply. Capacity for handling simultaneous targets is important for "wave" attacks, and was modeled by assigning a TIMINT of 0.1 seconds. Leakage and ammunition supply are important for attacks where the channel capacity of the defending ship is sufficient to handle the attack rate, as modeled by assigning a TIMINT of 1000.0 seconds.

The relationship between a ship's capacity value at 0.1 seconds and its capacity at 1000.0 seconds is determined by the individual weapon suite. Unfortunately, there is no method for determining one value from the other. For example, the FFG 7 class capacity at 0.1 seconds is 2 missiles; its capacity at 1000.0 seconds is 19 missiles or a 950% gain. For the CG 47 class, at 0.1 seconds the capacity is 30 and at 1000.0 seconds 60, or a 100% gain. With the wide varience in results between the various systems, values for the extremes were generated by using the LASMADS simulation.

Figures 12 through 17 show the results of a series of scenarios with one CG 16 class cruiser engaging Class 2

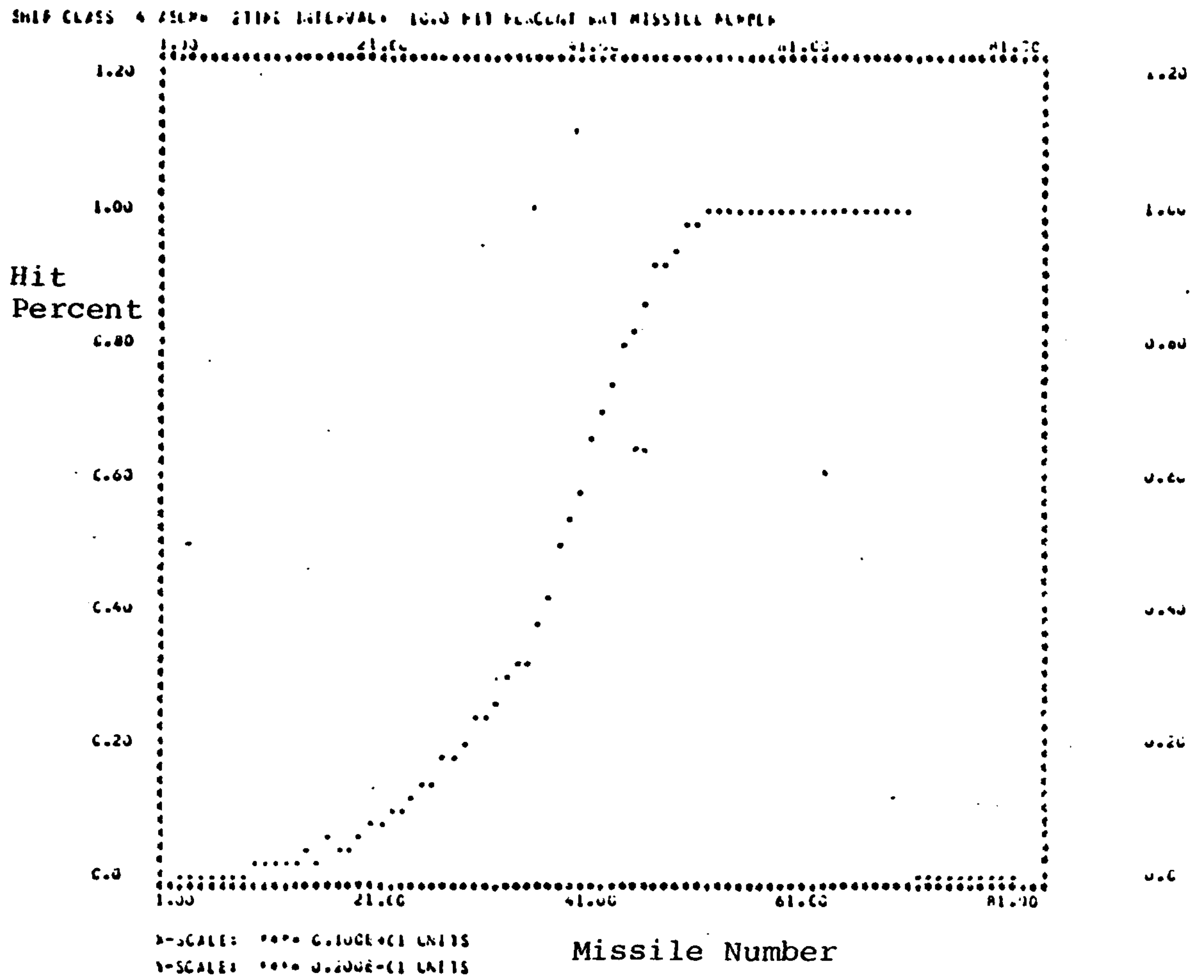


Fig. 12

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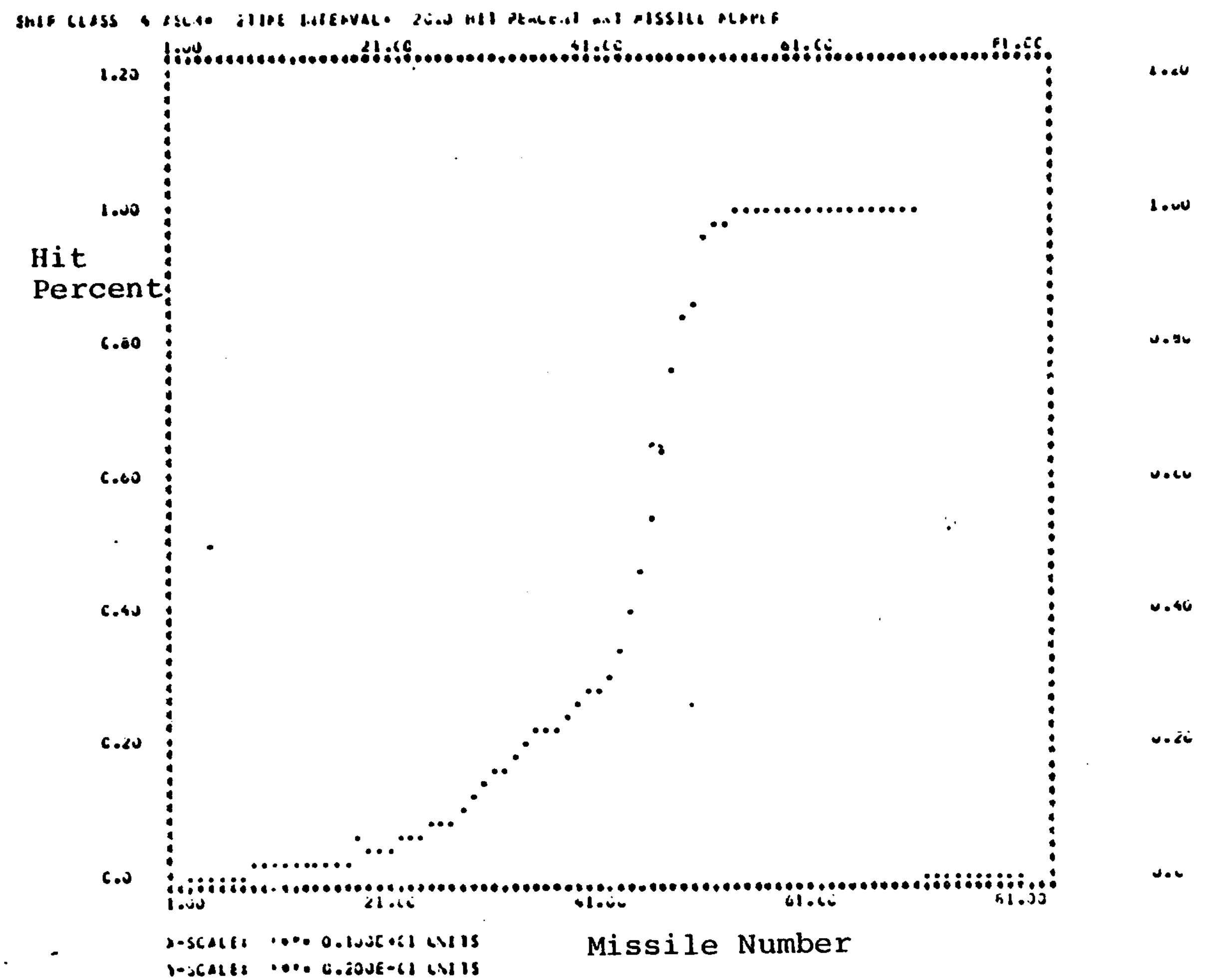


Fig. 13

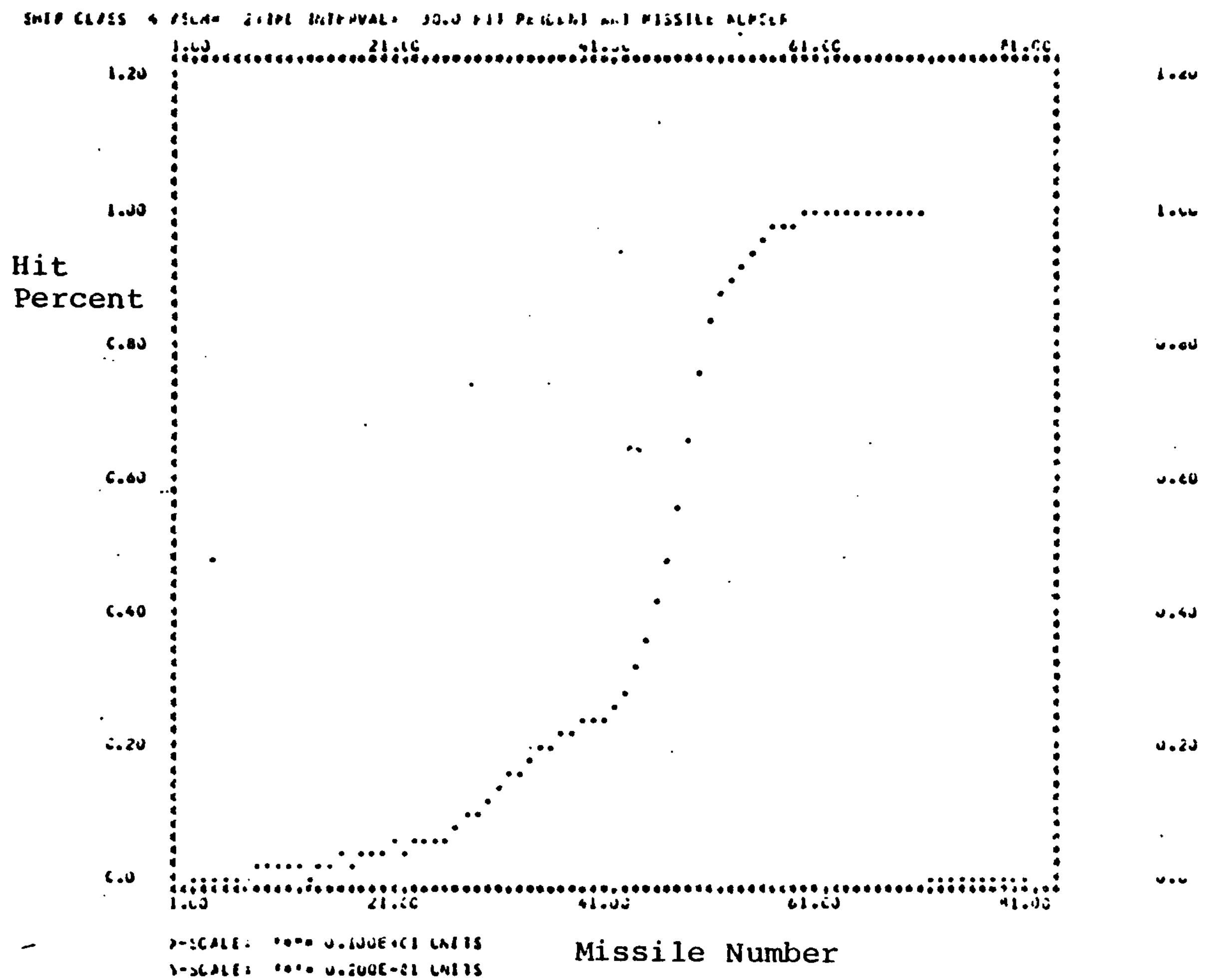


Fig. 14

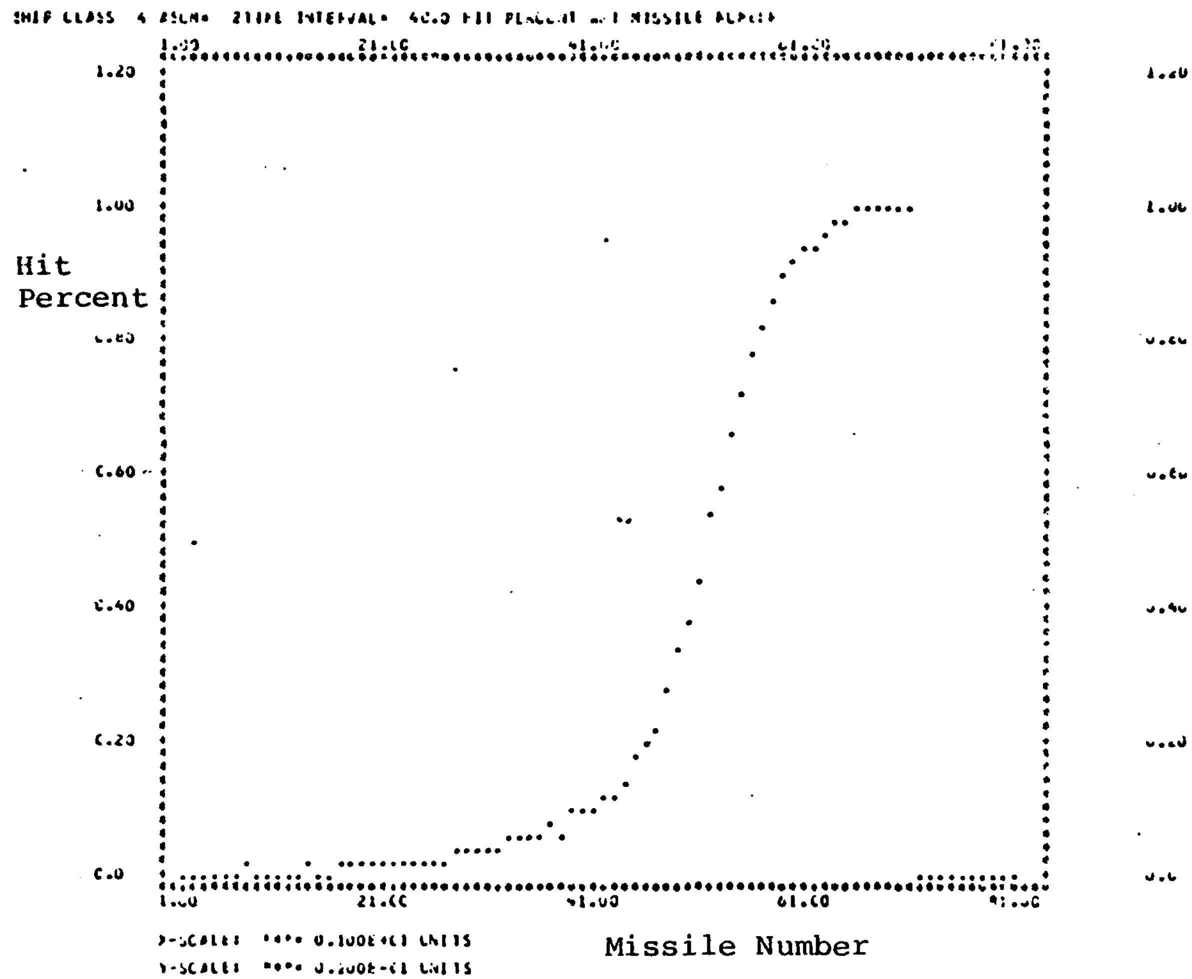

Hit
Percent
1.20
1.00
0.60
0.40
0.20
21.00
41.00
61.00
Missile Number

Fig. 15

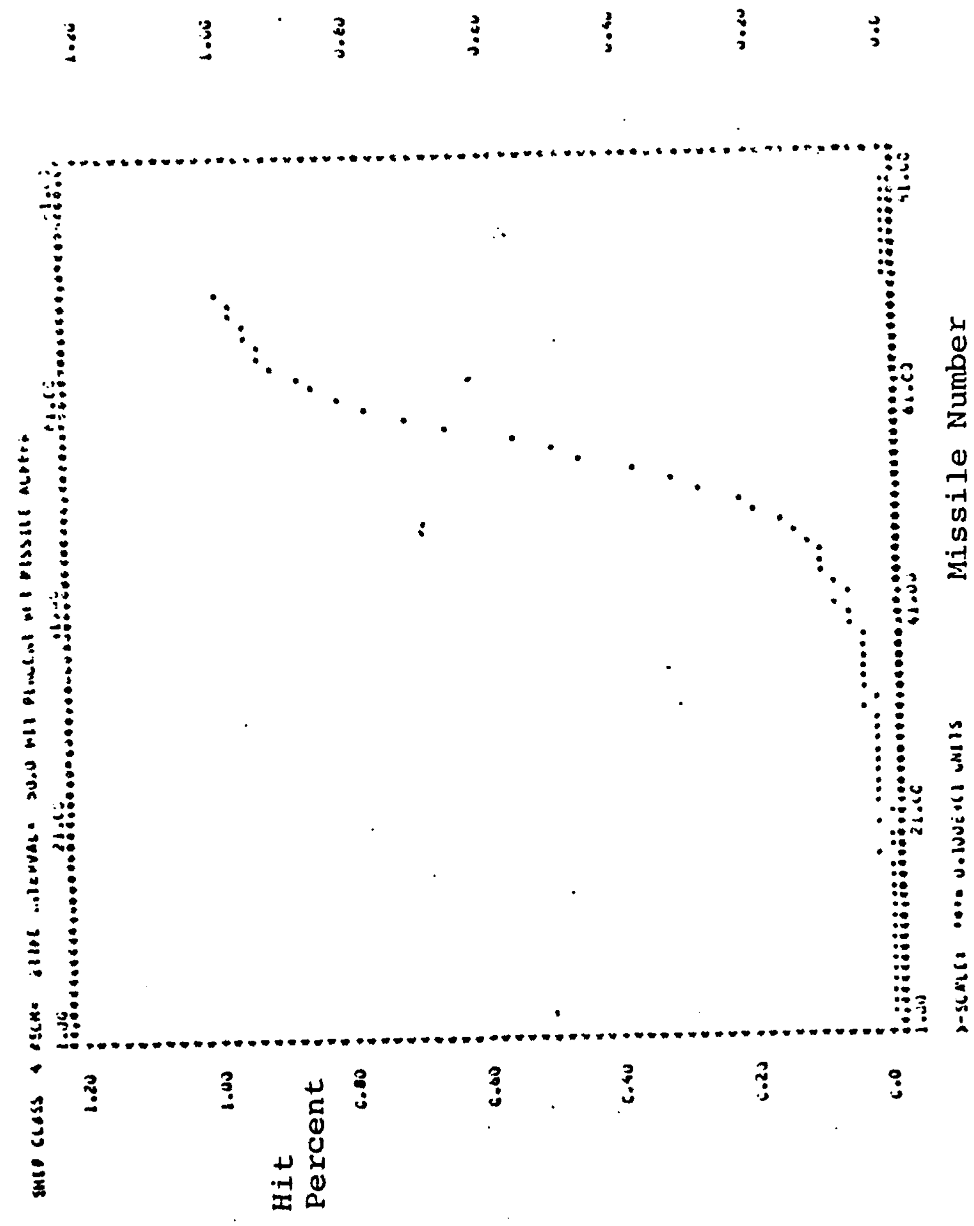


Fig. 16

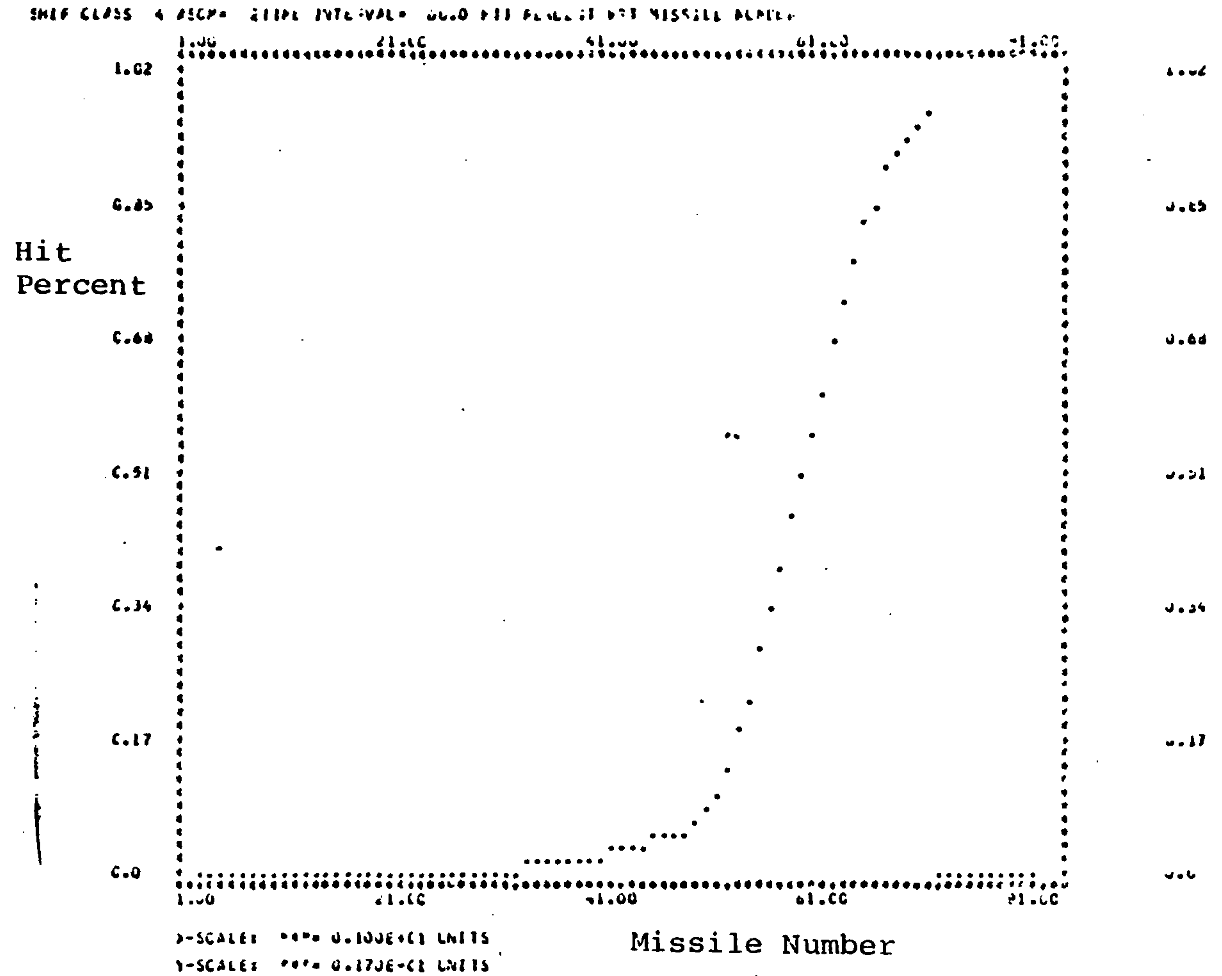


Fig. 17

ASCMs incoming at various TIMINT. The TIMINTs vary between 10 seconds to 60 seconds. Figure 18 superimposes the 10 and 50 second curves for comparison; evidently the effect of changing TIMINT is to shift the curve to the left or right, while maintaining approximately the same slope. As TIMINT increases, so does the capacity and collapse values. From this example the general question was then to resolve how the values progressed from one extreme to the other as TIMINT was varied.

Intuitively there should be no change until a certain threshold was reached. Similarly there should be a maximum value above which no change should be evident (100.0 seconds was chosen as the simulation parameter because it was greater than the flight time of any of the ASCMs considered, and thus safely above the maximum value).

Figure 19 shows a plot of the capacity value for the FFG 7 class plotted against TIMINT. The plot was generated by running the LASMADS simulation using the FFG 7 class ships in the base case scenario with varying TIMINT. Three scenarios are plotted, one with two FFG 7, another with three FFG 7 and the last with four. In each case there is no response in the capacity value until a threshold TIMINT is reached; after that point, the capacity value rises linearly until it reaches its maximum value. Superimposed on the three-ship plot is a line which represents the model

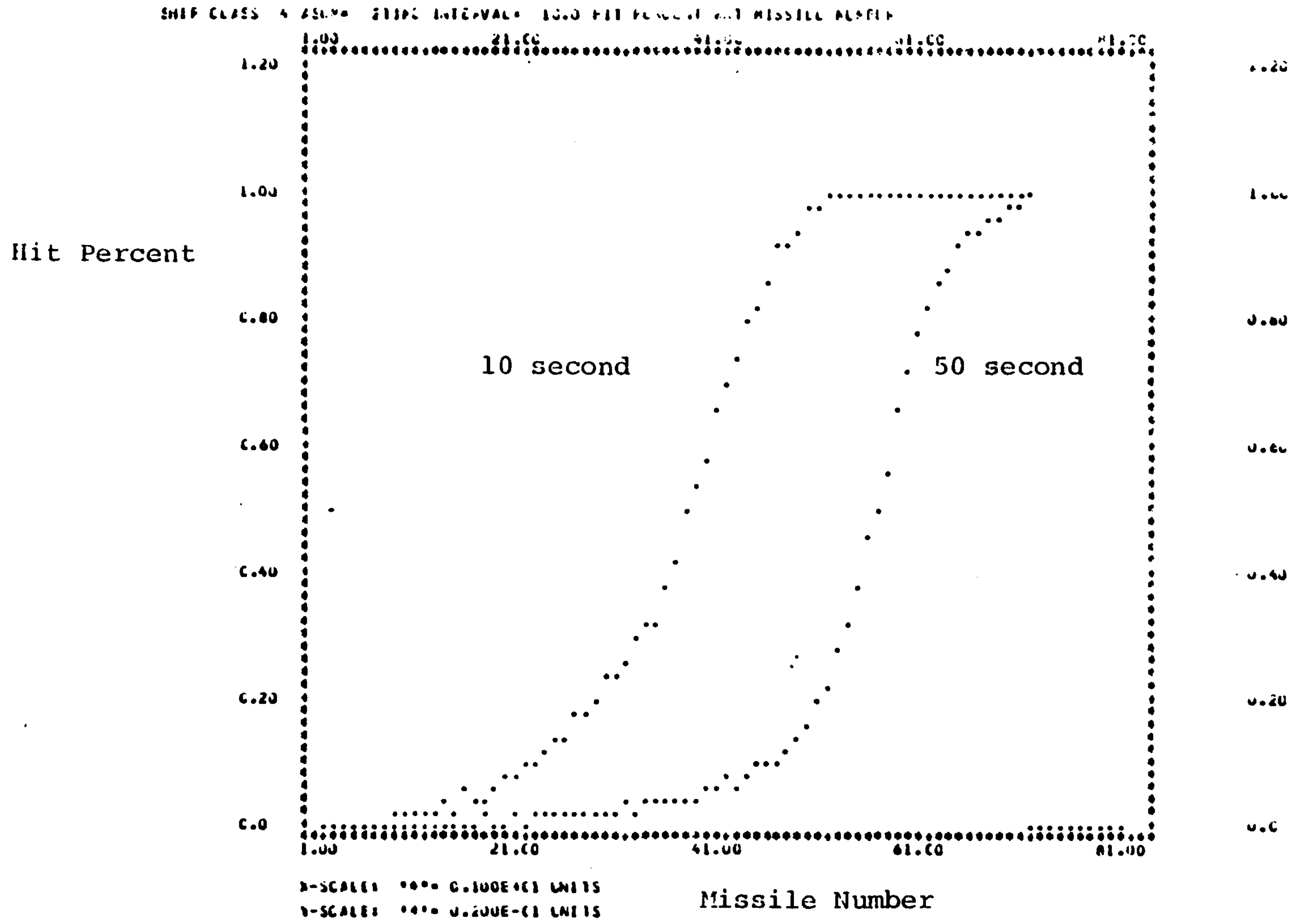
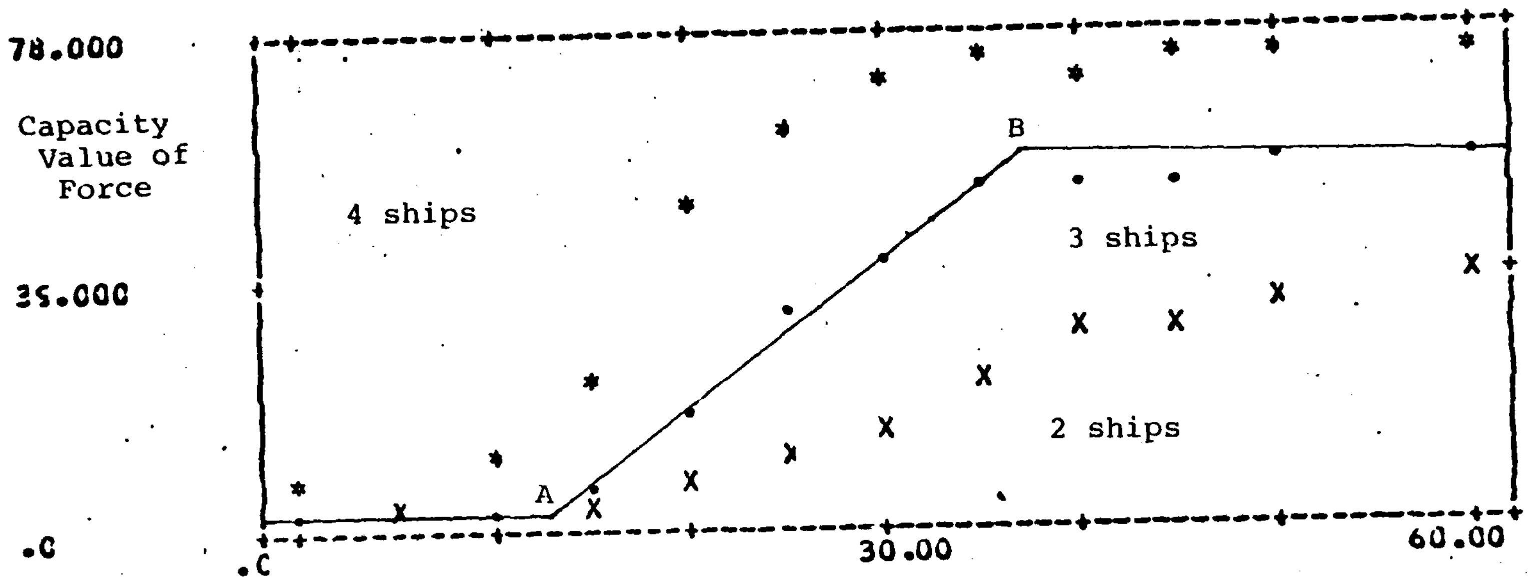

Hit Percent
10 second
50 second
Missile Number
1.20
1.00
0.80
0.60
0.40
0.20
0.0
1.00
21.00
41.00
61.00
81.00

Fig. 18



X-SCALE: "-"= 0.750E+00 UNITS   Time Interval

Y-SCALE: "|"= 0.130E+01 UNITS

A = lower inflection point

B = upper inflection point

PLOT CF SATLRATICN VALLES VS TIMINT

FFG7 FERRY CLASS   RADAR 1EC

2 SHIP = X
3 SHIPS = DCT
4 SHIPS = *

ALL SHIPS CN ATTACK AXIS

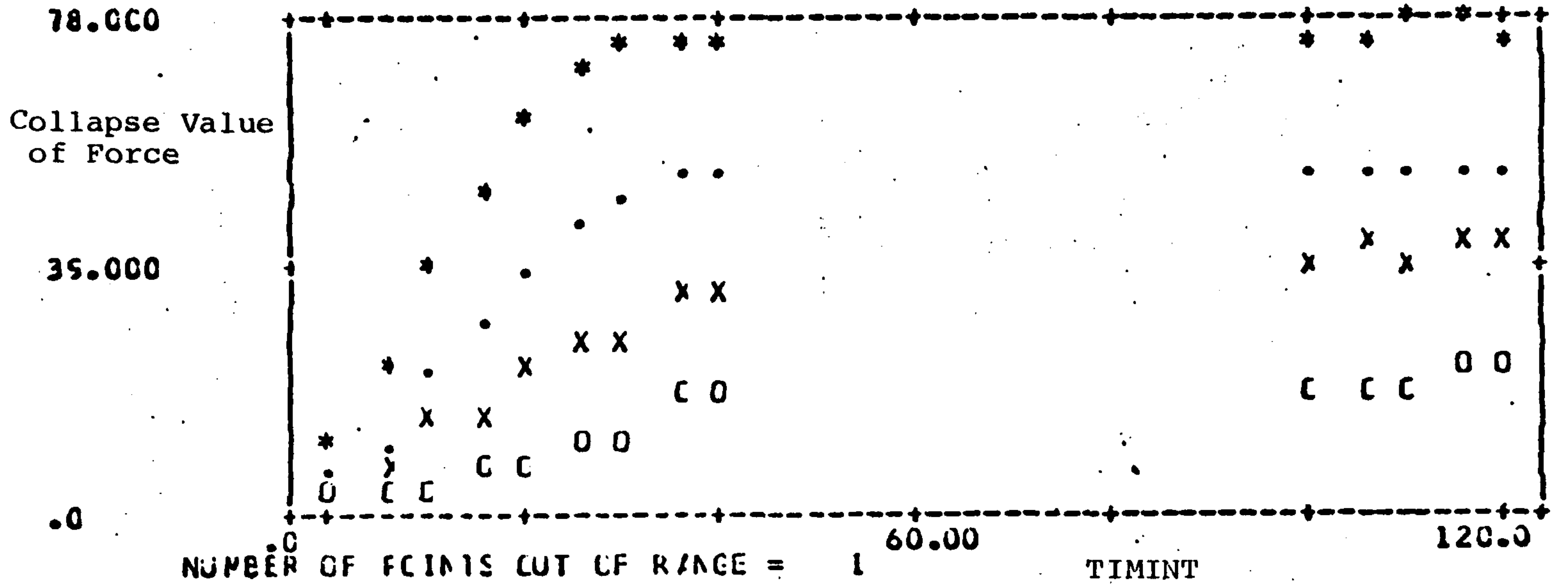
Fig. 19

for the behavior of the capacity and collapse values with varying TIMINT. Point "A" represents the lower inflection point; any TIMINT smaller than this value has no effect on the value. Point "B" represents the upper inflection point; at this TIMINT or above, the ship can reach its full capacity.

Note that there is a difference in the threshold values and the slopes of the lines between the three cases. In particular, the slope of the two-ship case is approximately twice that of the one-ship case, and the three-ship case three times. This is understandable because, for instance, in the two-ship case each individual ship need only engage every other missile. The individual missiles will be targeted 50% at one ship and 50% at the other so the effective targeting rate of each ship is cut in half. If the TIMINT of the ASCMs was 15 seconds, each ship would be effectively in a TIMINT = 30 seconds engagement.

Figure 20 shows a comparable behavior by the collapse value. Testing of representatives from the other classes of ships showed equivalent behavior.

Consequently, the 0.1 second case and the 1000.0 second case define the extremes of performance that a ship may have depending upon the TIMINT of the incoming ASCM stream. As TIMINT varies between the extremes, so does the ship's Capacity and Collapse values. This behavior is modeled from the results of the above experiments.



NUMBER OF POINTS OUT OF RANGE = 1

X-SCALE: "-"= 0.150E+01 UNITS

Y-SCALE: "|"= 0.130E+01 UNITS

PLOT OF COLLAPSE VALUES VS TIMINT

FFG7 PERRY CLASS RADAR 1EC

1 SHIP = O AXIS 1
2 SHIPS = X AXIS 1,0
3 SHIPS = DOT AXIS 1,0,2
4 SHIPS = * AXIS 1,0,2,1

Fig. 20

The change in capacity and collapse values with respect to TIMINT is modeled as consisting of two values: a threshold value below which no change is evident, and an upper value where full potential is reached, with a straight-line between. To determine where the ship falls on this curve, a standard curve with standard inflection points is determined, and the "equivalent" TIMINT is used. The equivalent TIMINT is defined as the actual TIMINT divided by the number of area defense ships present in the engagement.

The numerical value of the upper and lower inflection points will be dependent upon the amount of time it takes for the various ship's defensive systems to complete an engagement. They will be dependent upon cycle time of the weapon system, assessment time, and velocity of the SAM. The values used in the final model should be considered as only approximations consistent with the particular parameters used in LASMADS.

2. Variables Affecting Area Defense Performance

As an introductory example, consider a hypothetical case of a SAM ship with only one area defense battery, no point defenses, and vulnerable to complete destruction when hit by only one ASCM. Consider that the ship has an infinite supply of ammunition, and that the P-K of the defending missile is 1.0, a guaranteed kill. The ASCMs arrive at a time interval wide enough to allow each to be engaged by the SAM ship. In this case the SAM ship will be able to destroy an infinite number of ASCMs.

For the example, let us define the "value" of the ship as the number of ASCMs it would destroy before the ship itself is destroyed. In this example the value of the ship would be infinite.

However, if the size of the magazine was limited to 100 rounds, then the defensive value of that ship would be 100, and the 101st missile would penetrate and destroy the ship.

Now consider the ship with the 100 round magazine, and now supply the ship with a SAM with a P-K of 0.90. Run a large number of the engagements. The value of the ship would not be 90 as might be expected by multiplying the number of rounds by the P-K, but only approximately 10. Since each ASCM has a 10% chance of survival, on average every 10th missile will penetrate the ship's defenses, destroying it and the remaining rounds in the magazine.

Now consider the same ship, same SAM, but install a CIWS system which has the capability to destroy the first ASCM to penetrate the SAM defenses. Run the engagements and the value of the ship will be discovered to have increased to 20. Every 10th missile on average penetrated the SAM defenses still, but in this case the first one was destroyed by the CIWS system. When the second penetrator arrived, the CIWS was out of ammunition, so on average the 20th missile would destroy the ship.

This simple example demonstrates two important points:

First, that there is a need for a balance between area and point defenses in a ship's defensive suite. Providing a ship with a large number of missiles with a very high P-K is futile if the ship does not have the point defense capability to handle ASCMs that leak past the SAM defenses. Area defense systems will destroy more ASCMs only if they survive long enough to engage additional targets.

Second, that there is an interactive nature to the problem. The variables are the P-K of the SAM, the number of opportunities it has to fire on each incoming ASCM (number of possible intercepts), and the point defenses on the ship.

a. Firing Doctrine

As stated before, the firing doctrine used in the LASMADS simulation was "shoot-look-shoot-shoot," or rather "shoot-look-salvo." However, from the example with the mythical ship, this may not be the optimum firing doctrine. When the ship was fitted with the 0.9 P-K SAM and did not have the CIWS, it effectively had 90 rounds destroyed in the magazine by the leaking ASCM. If the ship, instead of firing only one SAM per ASCM had fired two, the P-K per ASCM would have increased to .99, the expected leaker would have been the 100th ASCM, the ship would have run out of ammunition as the limiting factor, and the value would thus have approached

50. Thus firing doctrine can have an important effect on ship survivability.

To illustrate this, two scenarios were run using the LASMADS simulation. In the first, two DDG 2 class ships defended against a cruise missile attack using a "salvo-look-salvo" doctrine against Class 2 ASCM at 10.0 seconds. In the other run, the same scenario was used with a "shoot-look-salvo" doctrine.

Tables 11 and 12 illustrate the results. The scenario using "salvo-look-salvo" increased both the capacity and collapse values of the group, and shot down approximately 10% more ASCM. In a similar test using only one DDG 2 with the range reduced to allow only one intercept, the ship using the salvo doctrine shot down 18% more ASCMs than the ship firing single SAMs.

The DDG 2 class vessel was particularly chosen because of the weakness of its point defense systems. A similar test using CGN 38 class vessels (with full CIWS/ECM mod equipment installed) yielded no effective difference between the two doctrines. The point is that there is no one optimum firing doctrine for every situation and every ship. Gains can be made in ship performance by tailoring its doctrine to its defensive capabilities and the situation. However, the adjustment of firing doctrine to match the characteristics of the actual battle would be very tricky to accomplish. As such, a uniform policy would probably be

TABLE 11

ATTACK STATISTICS		DEFENSE STATISTICS	
NUMBER OF ATTACKING ASCM	100	NUMBER OF DEFENDING SHIPS	2
ASCM MISSILE CLASSIFICATION	2	NUMBER OF AREA DEF SHIPS	2
SECONDS BETWEEN MISSILES	10.0	NUMBER AREA DEFENSE BATTERIES	4
NUMBER OF WAVES	1	NUMBER SELF DEFENSE BATTERIES	4
HVT TARGETING	0	NUMBER AREA DEFENSE RNDS INIT	80
PERCENT HVU TARGETING	0.0	RADAR RANGE	30.0
AUGMENT PERCENTAGE	0.0	ECM CYCLE TIME	24.0

RESULT OF THE ENGAGEMENT OVER 500 REPLICATIONS

		PERCENT
AVERAGE TOTAL HITS ON SHIPS	88.08	0.881
AVERAGE TOTAL SHIPS DUD	2.00	1.000
AREA DEF BATTERIES REMAINING	0.0	0.0
SELF DEF BATTERIES REMAINING	0.0	0.0
AREA DEF ROUNDS REMAINING	0.0	0.0
AREA DEF ROUNDS DESTROYED	51.50	0.644

INDIVIDUAL SHIP STATISTICS

NUMBER	CLASS	TYPE	POSITION	AXIS
1	5	2	0.00	1
2	5	2	0.10	1

SHIP	#1 BATS	#2 BATS	#PC SAM	#PC GUN	#CIWS	#ECM
1	0	2	0	2	0	0
2	0	2	0	2	0	0

SHIP	#TARGETED	#HITS	#KILLS	RNDS REM
1	50.31	44.29	5.51	0.0
2	49.69	43.79	6.40	0.0

SYSTEM PERFORMANCE OF INDIVIDUAL DEFENSES

	KILLS	RDS EXP	# SINGLE	# SALVO
LONG RANGE AIR DEFENSE SAM	0.0	0.0	0.0	0.0
INT RANGE AIR DEFENSE SAM	11.48	28.50	0.0	14.25
POINT DEFENSE SAM	0.0	0.0		
MEDIUM CALIPER GUN	0.44	4.52		
CIWS GUN	0.0	0.0		
ELECTRONIC COUNTERMEASURES	0.0	0.0		

SATURATION= 5 COLLAPSE= 11

TABLE 12

ATTACK STATISTICS		DEFENSE STATISTICS	
NUMBER OF ATTACKING ASCM	100	NUMBER OF DEFENDING SHIPS	2
ASCM MISSILE CLASSIFICATION	2	NUMBER OF AREA DEF SHIPS	2
SECONDS BETWEEN MISSILES	10.0	NUMBER AREA DEFENSE BATTERIES	4
NUMBER OF WAVES	1	NUMBER SELF DEFENSE BATTERIES	4
HVU TARGETING	0	NUMBER AREA DEFENSE RNDS INIT	80
PERCENT HVU TARGETING	0.0	RADAR RANGE	30.0
AUGMENT PERCENTAGE	0.0	ECM CYCLE TIME	24.0

RESULT OF THE ENGAGEMENT OVER 500 REPLICATIONS

		PERCENT
AVERAGE TOTAL HITS ON SHIPS	88.92	0.889
AVERAGE TOTAL SHIPS OOC	2.00	1.000
AREA DEF BATTERIES REMAINING	0.0	0.0
SELF DEF BATTERIES REMAINING	0.0	0.0
AREA DEF ROUNDS REMAINING	0.0	0.0
AREA DEF ROUNDS DESTROYED	56.44	0.706

INDIVIDUAL SHIP STATISTICS

NUMBER	CLASS	TYPE	POSITION	AXIS
1	5	2	0.00	1
2	5	2	0.10	1

SHIP	#1 BATS	#2 BATS	#PC SAM	#PC GUN	#CIWS	#ECM
1	0	2	0	2	0	0
2	0	2	0	2	0	0

SHIP	#TARGETED	#HITS	#KILLS	RNDS REM
1	50.23	44.78	4.78	0.0
2	49.77	44.14	6.31	0.0

SYSTEM PERFORMANCE OF INDIVIDUAL DEFENSES

	KILLS	RDS EXP.	# SINGLE	# SALVO
LONG RANGE AIR DEFENSE SAM	0.0	0.0	0.0	0.0
INT RANGE AIR DEFENSE SAM	10.68	23.56	6.08	8.74
POINT DEFENSE SAM	0.0	0.0		
MEDIUM CALIBER GUN	0.41	4.45		
CIWS GUN	0.0	0.0		
ELECTRONIC COUNTERMEASURES	0.0	0.0		

SATURATION= 4 COLLAPSE= 9

established by higher authority as a matter of doctrine. Given that, it was decided use exclusively the "shoot-look-salvo" doctrine for area defense batteries and accept any distortion of results that might result in individual cases.

The situation for point defense missile systems was slightly different. In the Endgame routine, each layer of defense was given one opportunity to engage the incoming ASCM. Originally, a P-K of 0.5 was assigned to PD SAM systems, and it was assumed that only one round was fired. However, after some experimentation it was discovered that the units fitted with PD SAM systems were being destroyed by leakers before the ship had fired half of the available magazine loads of missiles. Consequently, it was decided to assume that the firing doctrine for PD SAM was "salvo"; adjustments were made in the simulation by increasing the P-K to 0.75 and reducing the magazine load 50%. The effectiveness of the ships using this system increased as a result. Thus, a "RND EXP" in the summary table for the PD SAM system represents one engagement where two missiles were fired.

b. SAM Probability of Kill

The base case scenario, against Class 2 ASCMs, assigned the area defense missiles a P-K of 0.7. This P-K yielded the values determined in the 0.1 and 1000.0 TIMINT simulation runs. As in the hypothetical example discussed

above, any change in the missile P-K will require an adjustment of the value of the ship. There are two factors to be included in this adjustment:

First, the actual direct reduction of effectiveness of the defenses due to the reduced P-K of the SAM;

Second, the reduction due to the reduced survivability of the platform due to the increased number of leakers.

These were determined by using the LASMADS simulation. A base case scenario was run on all the ships available in the program with the only variance being the P-K assigned to the area defense missiles. P-Ks of 0.1 to 0.9 were run, sequencing by 0.1. Because some of the capacity and collapse values are very small and thus not very sensitive to change (the program generates integer capacity and collapse values), the measure of effectiveness was the total number of ASCMs destroyed by the ship's area defense batteries.

With these numbers it was determined that the results were generally independent of the nationality of the vessel. There was variance in the results, most of which could be attributed to the quality of the point defense systems installed on the ships. However, those cases were few. Thus an aggregated result was used, instead of attempting to assign individual values for each ship class.

The aggregate figures were normalized to the base case and averaged over the universe of ship classes. The two effects were separated by dividing the resulting value by (P-K/0.7).

The results are shown in Table 13. The "effectiveness factor" is defined as the change in capacity and collapse values directly due to the change in effectiveness of the SAM (i.e., the change in the P-K). The "survivability factor" is defined as the change in the capacity and collapse values attributable to battle damage resulting from the changed number of leaking ASCM caused by the change in the P-K of the SAM. These are multiplicative factors.

As an example, consider the calculation of the capacity value for the CG 26 class cruiser in the 1000.0 TIMINT case. The tabulated value of this ship from Table 10 is 27. Suppose the SAM missile on this ship is assigned the P-K value of 0.4. To obtain the corrected capacity value, the tabulated value is multiplied by the effectiveness factor (0.4/0.7) and multiplied by the survivability factor (0.88), both factors obtained from Table 13. The result (13.58) is the corrected capacity value for the cruiser in the 1000.0 TIMINT case when a missile with a P-K of 0.4 is carried.

c. Degradation Factor due to Reduced Detection (Radar) Range

One of the advantages of a longer range radar and a longer range SAM is that multiple engagements of a

TABLE 13

EFFECTIVENESS FACTOR OF SAM vs P-K

P-K	.1	.2	.3	.4	.5	.6	.7	.8	.9
Effect	.1/.7	.2/.7	.3/.7	.4/.7	.5/.7	.6/.7	1	.8/.7	.9/.7

SURVIVABILITY OF SHIP FACTOR vs P-K

P-K	.1	.2	.3	.4	.5	.6	.7	.8	.9
Survivability	.61	.71	.82	.88	.94	.98	1.0	1.02	1.03

single incoming ASCM are possible. If the first round fired misses, there remains sufficient range to fire another SAM to intercept outside the minimum range of the SAM system.

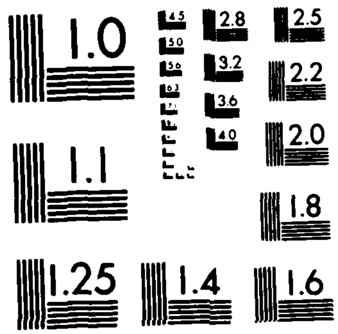
The number of intercepts possible will be determined by the radar range, the time required to establish a firm track, the speed of the ASCM and the SAM, and the assessment time. Figure 21 shows a plot of radar range vs ASCM speed--the lines on the plot show the thresholds between two different possible numbers of intercepts. The assessment times and tracking time were those of the base case scenario with the SAM velocity set at mach 2.0.

One thing to note is the step nature of this plot. For example, if you detected a mach 3.0 ASCM at 100 nm, you would have the opportunity for three intercepts. If you detected that missile at 175 nm, you still would get only three intercepts. The width of this detection plateau suggests that the correction factor to account for the range of detection effect should be a step function based on the number of intercepts achievable.

Table 14 is a theoretical look at the problem based on combining the effects of the P-K of the missile, the missile loadout, and the number of intercepts possible, and determining the extent of the point defense system needed. The firing doctrine is the base case doctrine.

AD-A138 781 AAW FIREPOWER INDEXING FOR NAVAL COMBATANTS(U) NAVAL POSTGRADUATE SCHOOL MONTEREY CA A D ZIMM SEP 83 2/3

UNCLASSIFIED F/G 15/7 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A

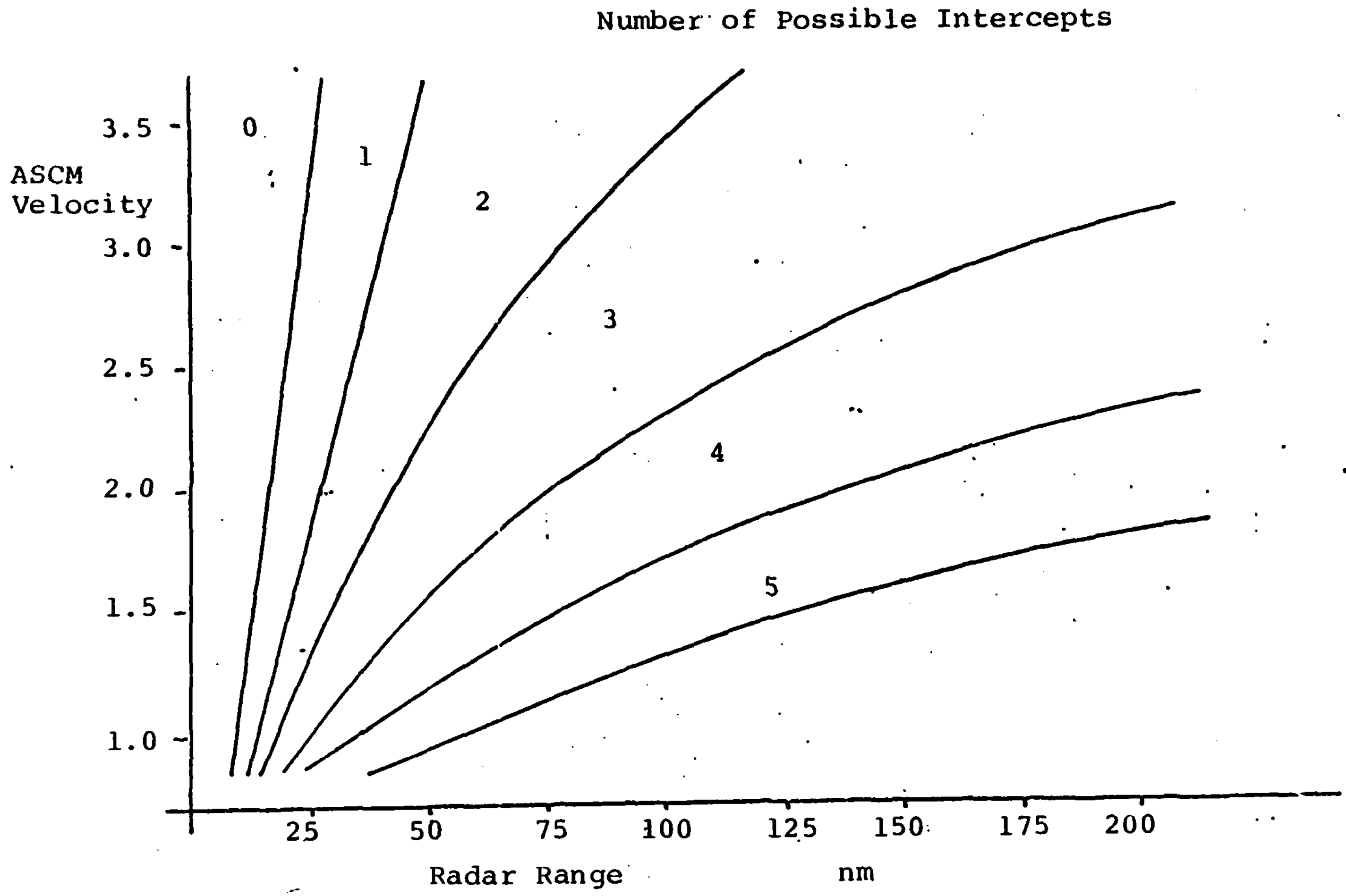

Number of Possible Intercepts
ASCM
Velocity
3.5
3.0
2.5
2.0
1.5
1.0
0
1
2
3
4
5
25
50
75
100
125
150
175
200
Radar Range
nm

Fig. 21

TABLE 14

Intercepts
Intercepts/Doctrine

P_K	1(2)	2(1-2)	3(1-1-2)	4(1-1-1-2)	5(1-1-1-1-2)
	RDS EXP/LEAK				
.9	2/.01	1.2/.001	1.12/.0001	$1.112/10^{-5}$	$1.1112/10^{-6}$
.8	2/.04	1.4/.008	1.28/.00016	$1.256/3.2X10^{-4}$	$1.2483/6X10^{-5}$
.7	2/.09	1.6/.027	1.48/.0081	1.444/.0024	1.433/.0007
.6	2/.16	1.8/.064	1.72/.0256	1.688/.0102	1.6752/.0041
.5	2/.25	2.0/.125	2.0/.0625	2.0/.0312	2.0/.0156
.4	2/.36	2.2/.216	2.32/.1296	2.392/.0778	2.435/.0467
.3	2/.49	2.4/.343	2.68/.24	2.876/.168	3.013/.1176
.2	2/.64	2.6/.512	3.08/.4096	3.464/.3277	3.7712/.2621
.1	2/.81	2.8/.729	3.52/.6561	4.168/.5905	4.7512/.5314

Expected Missile First Penetrator/RND Expended to First Penetrator
RND #/SAM EXP

.9	100/200	1000/1200	10000/11200	100000/111200	1000000/1111200
.8	25/50	125/175	6250/8000	3125/3925	16666/20971
.7	11.1/22.2	37.04/59.26	123.5/182.7	416.7/601.7	1428/2049
.6	6.25/12.5	15.63/28.13	39.06/67.19	98.04/165.49	243.9/408.58
.5	4.0/8.0	8.0/16.0	16.0/32.0	32.0/64.0	64.0/128.0
.4	2.78/5.56	4.63/10.19	7.72/17.90	12.85/30.75	21.41/52.14
.3	2.04/4.08	2.92/7.01	4.17/11.17	5.95/17.12	8.50/25.62
.2	1.56/3.12	1.95/5.07	2.44/7.52	3.05/10.57	3.82/14.39
.1	1.23/2.46	1.37/3.84	1.52/5.37	1.69/7.058	1.88/8.94

In the upper section, the P-K of the missile is one input and the number of interceptions the other. The body of the table gives the expected number of SAMs fired by the ship at each ASCM and the expected leakage percentage. For example, a ship with a SAM with a P-K of 0.4 with 3 intercept opportunities would be expected to fire 2.32 missiles at each ASCM and have a resulting leakage rate of 0.1296.

The lower section translates this information into the expected number of ASCMs destroyed before the first leaker and the number of SAM missiles expended to that point. Continuing the above example the ship would expect a leaker for every 7.72 ASCM and would have expended 17.90 SAM missiles up to that ASCM. If the ship had a magazine containing, say, 80 missiles, and had no point defenses, about 18 SAM missles would be expected to have been fired when the 19th ASCM penetrated and destroyed the remaining SAM missiles in the magazine. However, if the ship's point defenses can destroy the leakers, the SAM missiles in the magazine would have an opportunity to be used. In this case the point defenses would have to destroy almost five missiles (80/17.9) in order to be properly "matched" with the magazine capacity of the ship.

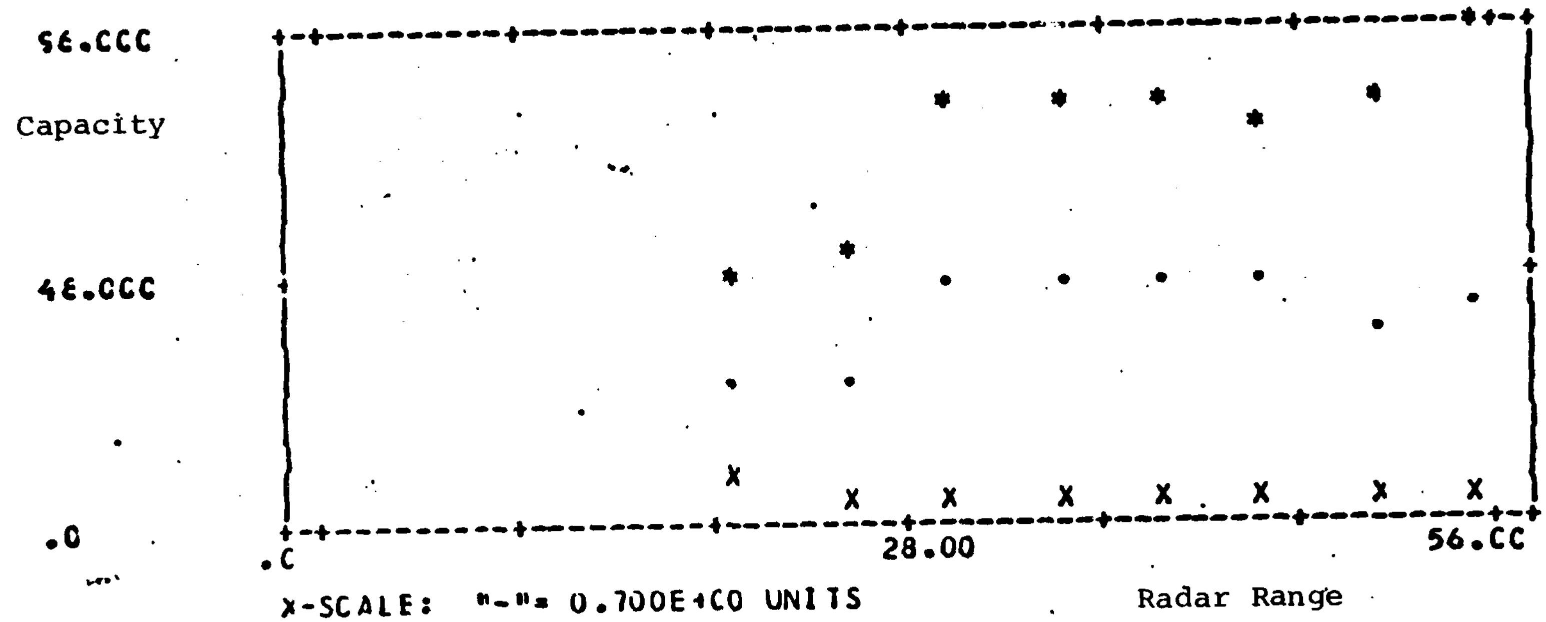
This analysis to some extent explains why the Soviet ships are designed with smaller SAM magazines and greater point defenses that U.S. ship. With a smaller P-K SAM,

you store fewer missiles on board rather than more and require more point defense systems.

The question still remains whether the factor adjustment which accounts for the detection range of the incoming ASCM should be a step function based on number of intercepts or a smoother curve. The argument for the assignment of the smoother curve is that any range advantage of detection is useful because the number of intercepts should be considered for the entire attack and not just one ASCM. While one ASCM is being engaged, the others are inbound, so the additional range advantage might allow enough time after the destruction of the first ASCM to shift targets and engage another ASCM.

This question was investigated using the LASMADS simulation. The base case scenario was run for several class ships and several TIMINTs, and the resulting capacity and collapse values plotted vs range of detection. Figure 22 shows a typical plot, this one for the capacity values for CGN 38 class ships. Within the limits of some data scatter, the values show the expected step increase at the threshold range. Figure 23 is a similar case, this one for the collapse value of the FFG 7 class.

A numerical value was assigned to this adjustment by running the base case situation with the universe of ships, varying the ranges of detection to ranges just at the threshold of a lower number of interceptions. The capacity



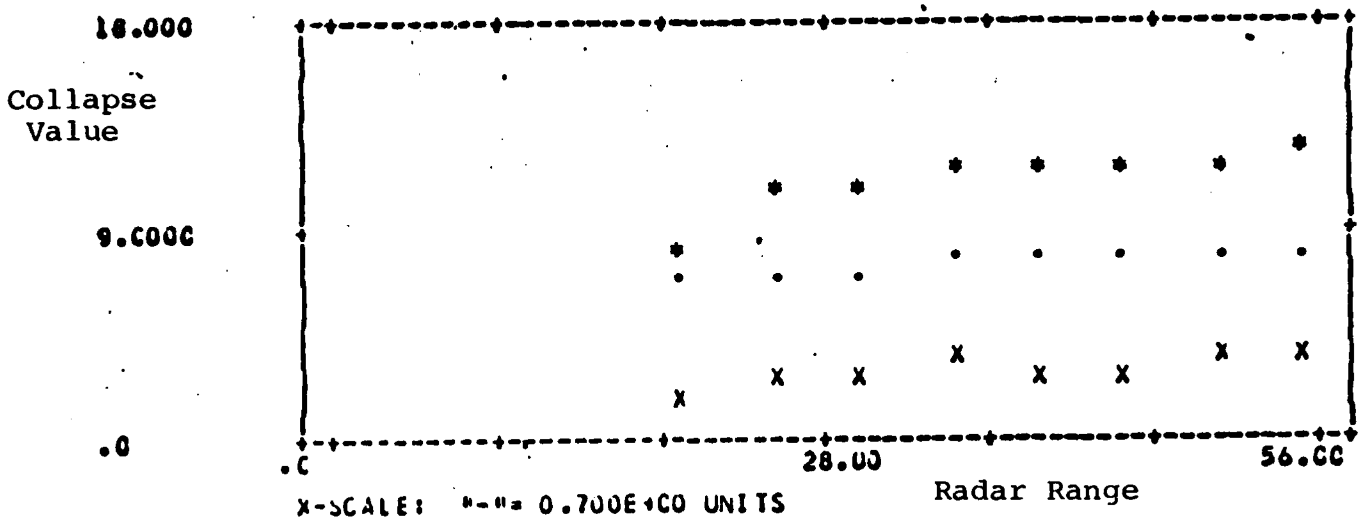
X-SCALE: "-"= 0.700E+C0 UNITS

Y-SCALE: "|"= 0.160E+C1 UNITS

FLUT CF SATLFATICN VALUES VS RADAR
CGN38 VIRGINIA CLASS TIMINT=15.0 SECCNDS

1 SHIP = X
2 SHIPS = CCT
3 SHIPS = *

Fig. 22



X-SCALE: "-"= 0.700E+CO UNITS

Y-SCALE: "|"= 0.300E+CO UNITS

PLOT OF COLLAPSE VALUES VS RADAR
FFG 7 PERRY CLASS

TIMINT 5 SECCNDS = X
TIMINT 10 SECCNDS = DOT
TIMINT 15 SECCNDS = *

Fig. 23

and saturation values were sufficiently sensitive as to allow their use directly in calculating the results.

Analysis was made for differences attributable to the nationality of the ship. In this case, the Soviet ships were seen to have a consistantly higher value. This is attributed to the better matching of the capabilities of the point defense and area defense systems on Soviet ships. Consequently, a separate tabulation was used for Soviet ships. In addition, there were sufficient differences in the behavior of the capacity and collapse values to warrant their separate calculation.

The results are shown in Table 15.

3. Additivity of Forces and Formation Effects

The tentative assumption made when approaching this question is that forces would prove to be additive or better than additive. The idea that, say, 8 air defense batteries would destroy twice the number of attacking ASCMs as 4 batteries is intuitively appealing. And, as discussed before, the adding of additional defenses would be expected to increase the value of the original batteries, because they would be able to survive longer and engage additional targets. In reality, there would be command-and-control considerations which would limit the effective size of any defending force; however, on the scale considered here, more units would certainly be more desirable than fewer. The

TABLE 15

FACTOR--NUMBER OF PRESENTATIONS

PRES	U.S. SHIPS FACTOR SATURATION	U.S. SHIPS FACTOR COLLAPSE	SOVIET SHIPS FACTOR SATURATION	SOVIET SHIPS FACTOR COLLAPSE
1	.52	.70	.33	.72
2	.60	.90	.66	.92
3	1.00	1.00	1.00	1.00
4	1.23	1.07	1.36	1.09
5	1.26	1.09	1.39	1.11

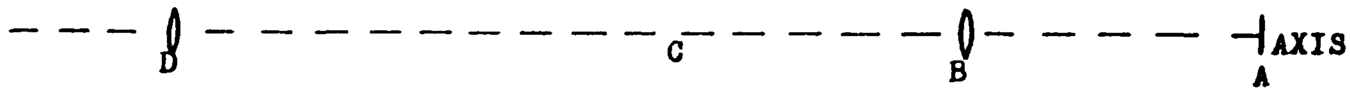
question is how the effectiveness values (capacity and collapse) combine when multiple units are present.

After testing using the LASMADS model it was discovered that forces were less than directly additive. Three factors were isolated in this effect:

First was the "off axis" problem. Ships that were located to the left or right of the axis of attack were most often engaging ASCMs located in a different plane of attack, and thus their P-K was reduced by the Off-Axis Degradation (OADEG) factor. The analysis discussed above demonstrated the effect of varying the P-K on the defensive value of a ship.

Second was the "rear ship" problem. When the attack level neared the capacity of the formation, more and more ASCM intercepts were made at close range. In some cases a rear ship would fire on an ASCM which would impact on a front ship before the rear ship's SAM could intercept the ASCM. This has the effect of eliminating an intercept opportunity and occupying the fire control battery to no avail. Figure 24 illustrates this situation.

Third was the "dead ship" problem. In some situations where one ship is out further on the attack axis, it can be quickly overwhelmed by the attack. When its point defenses are destroyed, the following missiles targeted on that ship have a "free ride" to impact. This, coupled with the "rear ship" effect, can artificially inflate the hit



REAR SHIP PROBLEM: ASCM "A" is targeted against ship "B".
Ship "D" engages ASCM "A" with a computed intercept point "C".
The ASCM hits the target before the intercept is effected.

Fig. 24

percentage of the incoming attack. The total number of hits inflicted by the ASCM attack is greater but without any additional effect on the battle group as a whole. Indeed, the "dead ship" is contributing to the defense by serving as a decoy and absorbing hits from ASCMs which would be more profitably targeted on other surviving ships.

Another curious effect is that while the off-axis condition affected both the capacity and collapse values, the other two conditions only affected the capacity, and did not have a discernable effect on the collapse value.

In the final model, additional area defense ships over and above the first were considered to have their capacity and collapse values reduced to 80% of original values. Area defense ships located on the left or right plane of attack were considered to be carrying a SAM with a P-K reduced by the OADEG for all engagements, and ship values modified accordingly. These were rough estimates only. The combinatorial effects of multiple ship formations is an area which further fruitful work could be accomplished.

4. <u>Factors Affecting the Leakage Value</u>

Most of the above discussion deals with factors influencing the capacity and collapse values. Most of their effects were isolated from influencing the leakage value. The "base case" method involved keeping the P-K of the point defense systems constant as a control. Consequently, the behavior of the leakage value was not directly

investigated. A separate series of tests were required to determine the behavior of the leakage factor.

Three conditions were isolated as having first order effects on the behavior of the leakage factor:

The number of intercept opportunities available to the area defense batteries;

The "difficulty" of the ASCM;

The "layers" of the formation.

a. Intercepts Factor

For ships with area defense batteries the SAM batteries are an integral component of the process determining the leakage value before capacity. As shown in Table 14, a greater number of intercept opportunities translates into a smaller leakage rate through the area defenses and a greater interval between leakers, thus allowing point defense systems time to engage. The correction factor for number of intercepts was determined by comparing the leakage rates generated by the universe of AD ships during the range dependence tests. It was found that having intercept opportunities greater than three had a negligible effect on leakage; however, leakage at two intercepts was approximately twice that of three and leakage at one intercept was approximately three times that of three.

b. ASCM "Difficulty"

The point defenses of a ship characteristically consist of many different systems. The performance of point

defenses against different ASCMs is not uniform. For instance, a CIWS system performs best against sea-skimming missiles and has difficulty with mach 2.0 intermediate altitude ASCMs. However, most PD SAM systems perform best against the latter and have difficulty with the former. Consequently, there is no gradiation of cruise missiles from "easiest" to "difficult." The difficulty of a cruise missile is entirely dependent upon the composition of the point defenses it faces.

Consequently, the ASCM "difficulty" factor can only be determined by simulating that missile against those defenses. In the final model, that is a free variable assigned by the operator (CAP). By simulation using LASMADS, the factors were 1.0 for CMCLAS 2 (the base case, a mach 2.0 intermediate altitude ASCM); 1.5 for CMCLAS 3 (a 3.5 mach high altitude ASCM); and 1.2 for CMCLAS 1 (mach 0.8 sea-skimmer).

c. Layer Effect

In large formations, attacking ASCMs which are targeted against ships in the rear of the formation have several successive layers of ships (and AD batteries) to penetrate. For instance, it might be engaged by an outer screen ship with three intercept opportunities and then an inner screen ship with several intercept opportunities and then still have to run the point defenses of the target ship. These successive "screens" provide a serious attrition effect

for the first ASCMs in the attack stream, up until the capacity of the formation is reached.

Deterministically quantifying this is very difficult because of the number of formations and formation variables involved. It essentially becomes a "best fit" variable input at the discretion of the operator, using the experience of observing the effect in several simulation runs.

The "layer" factor thus is used to reduce the leakage value by dividing the leakage rate calculated from the above factors. As a rule of thumb, this factor should vary from 1.0 (single ships) to 3.0 (a conventional U.S. 6-ship battle group) to 6.0 (large battle groups of over 14 ships). This factor divides the leakage rate so a higher assigned number results in a lower leakage rate.

Overall, the model for the determination of the leakage factor is subject to interpretation and is an area where work to refine the model is needed.

D. COMBINED AND SECOND ORDER EFFECTS

There are several aspects of the air defense problem which can be combined with other effects, while retaining the significance of its influence on the problem. The following are some of these aspects.

1. Jamming

Jamming can be characterized under two general categories:

* Jamming to reduce the effectiveness of search radar; and
* Jamming to reduce the effectiveness of fire control radar.

The effect of jamming of search radar is to reduce the range of detection of the incoming ASCM. At a certain range which is dependent upon the power of the jamming and the capabilities of the radar, the radar will "burn through" the jamming noise. In terms of the LASMADS simulation this would be represented as a reduction of the cookie-cutter radar range. In terms of the model, this reduction in the range would equate to a reduction in the possible number of intercepts.

The effect of jamming the fire control radar is less clear-cut. As mentioned when discussing the ECM problem, some electronic countermeasures are all-or-nothing: either they work or they do not. For some, the countermeasure could be equated to a reduction in the probability of a kill by the SAM system. If the latter assumption is made, the jamming of fire control radars would reduce to, in terms of the LASMADS simulation and the final model, a reduction of the P-K of the SAM missile.

2. Reduction of the Effectiveness of Command and Control

As discussed before, the LASMADS simulation assumes perfect command and control. Missiles are engaged in the optimum fashion. A reduction of the effectiveness of command and control of the defending forces can be characterized in two ways:

* As delays in the acquisition, tracking, handoff, and assessment times within each engagement; and
* as errors which allow missiles to completely escape engagement by area defenses, even though fire control channels (i.e., capacity) are available to engage the ASCM.

To explore the first effect, the LASMADS simulation was run using the Command and Control Degradation option. It was discovered that use of this option had a steplike effect on performance in some cases and no effect on others. The controlling variable was the proximity of the detection range to the threshold dividing one number of possible intercepts from another. For example, when engaging a mach 2.0 missile, there was no difference in detecting the missile at 100 nm or 175 nm--you still received only three possible intercept opportunities. However, a detection at 175 nm allowed 75 nm of "error time"--time which could be wasted in command and control errors and still have no effect on the number of potential intercepts. In the case where detection was made at 100 nm, if only a small amount of time was consumed in errors,

the potential number of intercepts would drop from three to two. Consequently, this factor could be accounted for by reduction in the number of possible intercepts.

The second possibility is more difficult to characterize. In the LASMADS simulation, this situation is simulated using the Penetration option. As shown in Tables 7 and 8 and Figures 4 and 5, the use of the Penetration option affects both the leakage and the capacity and collapse values. The actual effect has dependencies on the battle group size, formation, layers, and possibly others. This option was not explored in any depth and could be the subject of further investigation.

3. Multiple Wave Attacks

Figure 25 shows the plot of probability of hit vs missile number for a large attack against a U.S. CVBG consisting of one CV, one CGN 36, one DDG 2, one DD 963, one FFG 7, and one FFG 1052. Figure 26 is a plot of the same situation with the exception that the attack has been divided into two waves. Figure 25 shows the characteristic curve behavior of a period of low leakage below the battle group's capacity figure; and inflection point at capacity; and the linear rise in the hit probability per additional missile. Figure 26 shows exactly the same pattern with the exception of a drop in the hit probability at the beginning of the second wave. The drop is attributed to the opportunity

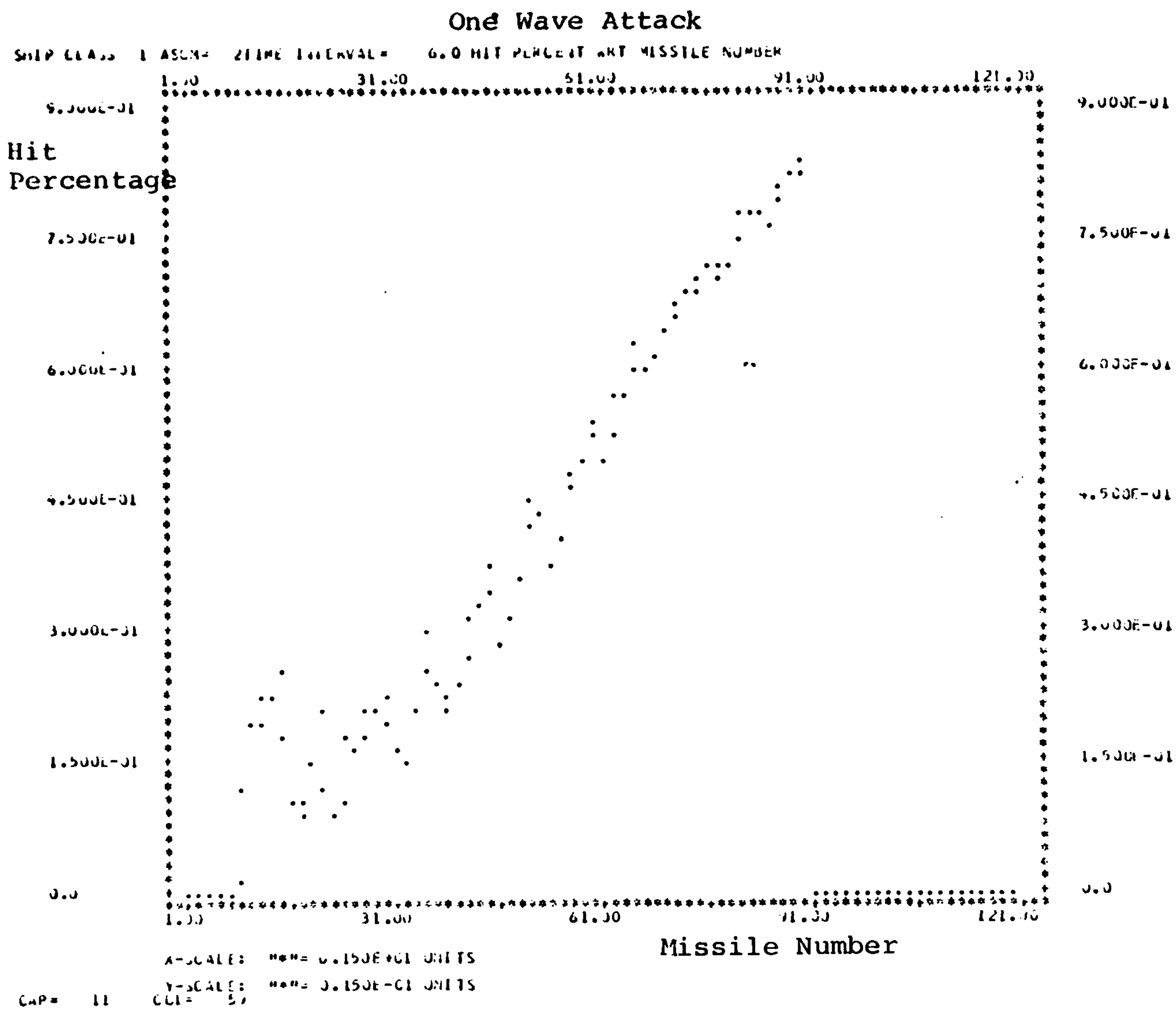

One Wave Attack
Hit Percentage
Missile Number
1.00
31.00
61.00
91.00
121.00
0.0
1.500E-01
3.000E-01
4.500E-01
6.000E-01
7.500E-01
9.000E-01
X-SCALE: ***= 0.150E+01 UNITS
Y-SCALE: ***= 0.150E-01 UNITS

Fig. 25

Two Wave Attack

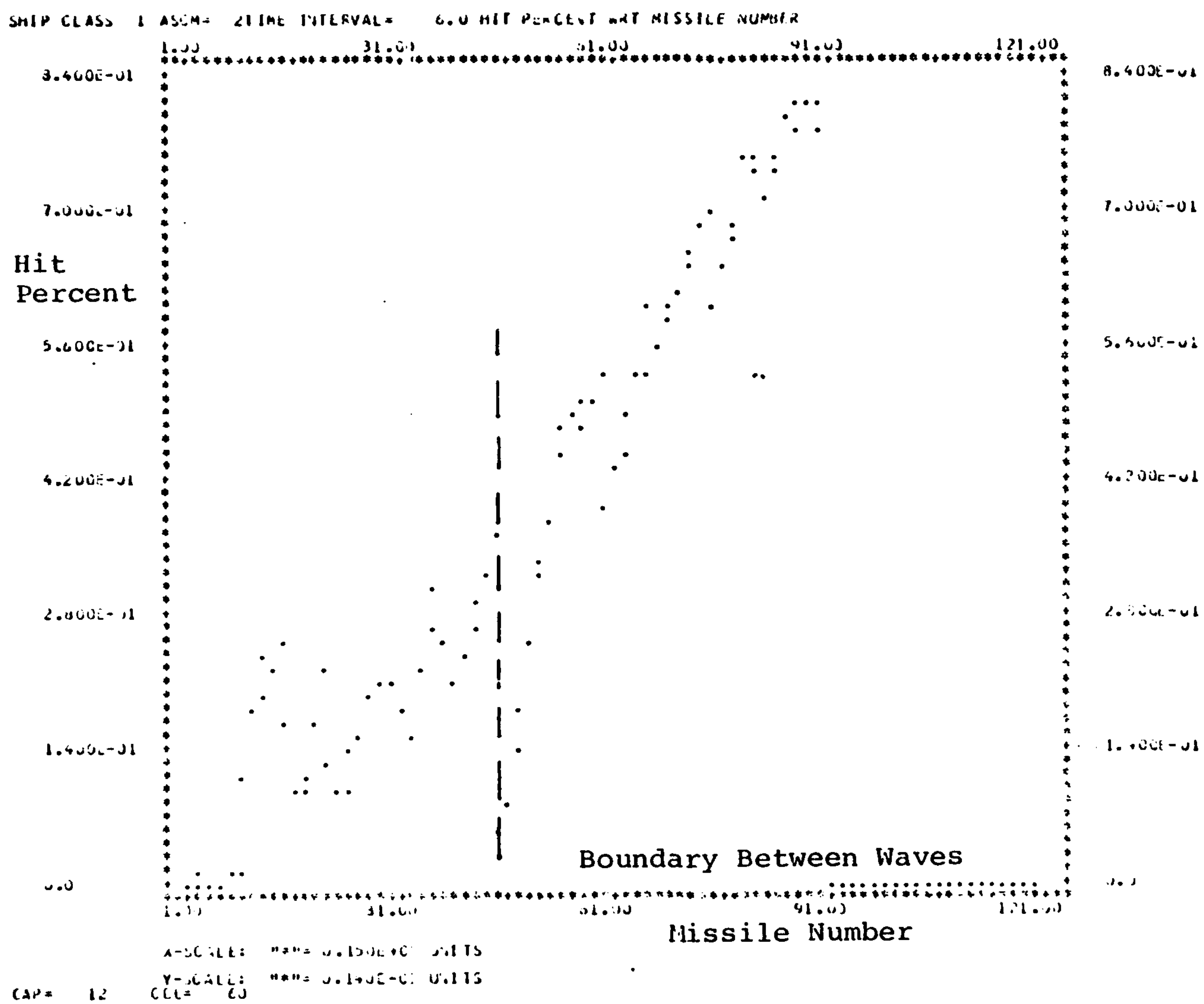


Fig. 26

provided to the defenders to complete their engagements and have all systems ready for the onset of the next wave.

Consequently, if the assumptions hold (i.e., that all the ships are afloat for the second wave and that no change in targeting method is used), then it can be seen that launching an attack in multiple waves is of no particular advantage. In addition, once the initial few missiles exceed the remaining capacity of the defenders, the probability of hit resumes the curve of the one wave attack. So, conceptually, once the remaining capacity is overcome in the second wave, the following missiles can just be considered as continuations of the first attack. This demonstrates the linear and cumulative nature of ASCM attacks on surface ships.

4. Decoys and Counter Targeting

In the LASMADS simulation, the operator has the option to include decoys in the formation. In the targeting phase, these decoys act just like ships: they possess a radar cross section and a priority in the targeting list and will be so targeted by the ASCMs.

There are several assumptions in this model:

* That the decoys are indistinguishable from other ships;
* That the decoys are close enough to the formations that ASCMs targeted against them are indistinguishable from other ASCM and thus

they are engaged in the same manner as the rest;

* That when an ASCM reaches the position of the decoy, the ASCM "disappears" and does not pass on to target another ship;
* That the decoy is unaffected by the ASCM.

Missiles which penetrate to the decoy are not recorded as "hits". Thus the result of including a decoy in the program is to reduce the number of hits and hit percentage of each missile by a factor approximately directly proportional to the decoy radar cross section divided by the total force radar cross section.

There is dependence on the location of the decoy in the formation. Decoys located well forward on the range axis (in the direction of the incoming attack) are the most effective and have an effect similar to the "dead ship" effect discussed above. They "absorb" and eliminate their targeted ASCMs early, thus eliminating them from potentially being fired on by rear ships. As a rule of thumb, a decoy located on the forward edge of the formation will be three times more relatively effective than a decoy located to the rear of the formation.

Beyond some simple experimentation, nothing further was done in the line of decoys/countertargeting, because some of the assumptions might be weak when compared to actual decoy performance. The lack of creditable, long-life

decoys in any fleet (with the exception of the helicopter, used extensively by the British in the Falklands as an anti-Exocet measure) precluded extensive work or inclusion of decoys in the final model. Given progress in this area, this might be a fruitful area for further work.

IV. THE AGGREGATE MODEL: SUMS

The final resulting model was automated in a program called SUMS. The name was simply suggested by the basic process: individual ship values were modified to account for the various circumstances of the attack, and then added together. The objective of the program was to generate the same net number of hits as the LASMADS simulation, using a much smaller and faster program.

The following discussion is likened to an algorithm: it is a step-by-step procedure, using the LASMADS simulation for determining numerical values.

A. DETERMINATION OF BASIC SHIP VALUES

STEP ONE: Run approximately 1000 replications of the ship against the base case ASCM type. In this study the mach 2.0 intermediate altitude ASCM should be used. To conform with the convention that these values generated should represent the best potential performance of the ship, the ASCM type chosen should be the type for which the defending weapon systems are the most effective in countering. The same type of ASCM is then used in evaluating all the ships. The detection range should be set to allow three intercept opportunities.

Perform one run at TIMINT = 0.0.

Perform one run at TIMINT = 1000.0.

From each of these runs extract the capacity, collapse and leakage values. These values are obtained from the printout which gives the hit percentage, cumulative hits, and cumulative hit percentage for each missile (for an example, see Table 4). The capacity value is the missile number where the hit percentage exceeds 10%. The leakage value is the cumulative hit percentage for the same missile. The collapse value is the missile number where the hit percentage exceeds 50%. The LASMADS simulation includes an output of the capacity and collapse values. At this point the values for the two different time intervals between attacking missiles remain segregated.

These five values are the "tabulated values" (or fire-power indices) of the ship.

STEP TWO: Determine the situational ship value.

The tabulated ship values for both TIMINT cases are multiplied by the following factors:

* To account for any difference in P-K of the missile from the base case, multiply the capacity and collapse values by (P-K/0.7).
* To account for the difference in ship's survivability due to the different P-K, multiply by the survivability degradation factor.

Both of the above factors are tabulated in Table 13.

It should be noted that this calculation, accounting for P-K variations, includes any P-K variation due to the location of the ship on the left or right plane of attack. If the ship is located on one of these planes, the P-K of the SAM are considered to be reduced by the OADEG factor.

* To account for the difference in detection range from the base case, multiply by the factor associated with the number of possible intercepts. This factor is tabulated in Table 15. Note that the number of intercepts allowed should take into account the range of the SAM. For instance, if the SAM has only sufficient range to allow two intercepts, it should use the two intercepts value for any detection range which allows two or more intercepts.

The values calculated above tailor the individual ship indices to the new circumstances. The next section calculates the combined values for the formation as a whole.

B. DETERMINATION OF AGGREGATE FORMATION VALUE

The capacity, collapse, and leakage values of the formation are treated separately.

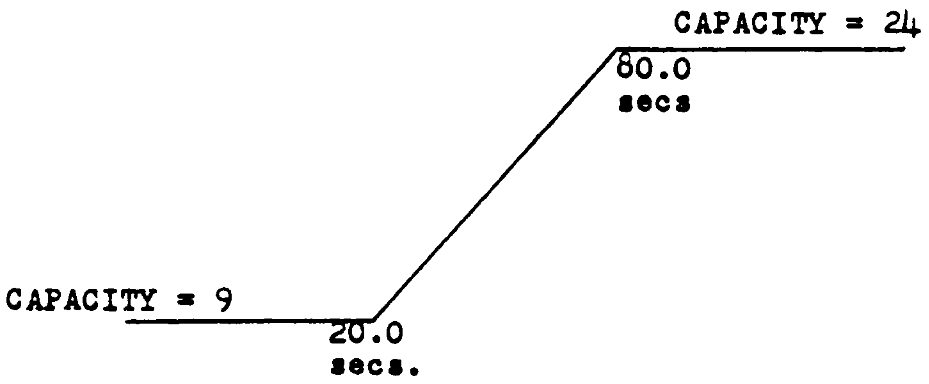
1. Capacity Value

* Add the 0.1 second values together. Add the 1000.0 second values together.
* If there are more than one ship in the formation, multiply the values by the "formation factor." This

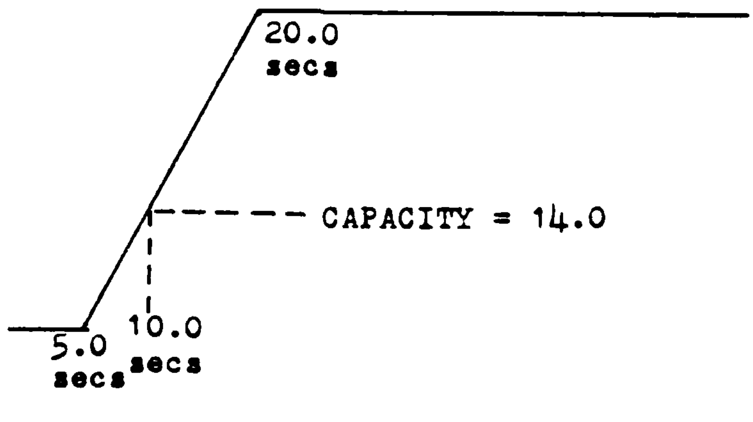
is the factor which accounts for "rear ship" and "dead ship" effects. For this model, an estimated formation factor of 0.8 was used. Thus the capacity value of each area defense ship over and above the first area defense ship was multiplied by this factor.

* Divide the TIMINT curve inflection points by the number of area defense ships; enter the TIMINT of the attack to determine the percentage along the interval that the TIMINT falls; that percentage will be the percentage along the interval between the 0.1 second and the 1000.0 second values. This is the net capacity value.

Figure 27 shows an example of this procedure. The capacity of a four-ship formation has the 0.1 TIMINT value of 9 and the 100,0 TIMINT value of 24. All the ships are area defense ships. The TIMINT of the attack is 10.0 seconds. The TIMINT inflection points are at 20.0 seconds for the lower, and 80.0 for the upper point. (Note that as discussed before, these are only estimated values.) The original TIMINT inflection curve points (Drawing A) are divided by four to give the new TIMINT curve (Drawing B). These new points are 5.0 seconds for the lower, and 20.0 seconds for the higher inflection point. The actual TIMINT of the attack, 10.0 seconds, is one third of the way between the two inflection points; thus the capacity value of the formation under



Drawing A



Drawing B

Fig. 27. Use of TIMINT and Inflection Points to Determine Capacity and Collapse Values.

this attack is one third of the way between the 0.1 second TIMINT value and the 1000.0 seconds TIMINT value or, in this case, one third between 9 and 24 is 14.0.

2. Collapse Value

The procedure for determining the collapse value is exactly the same as the procedure for determining the capacity value as described above. The inflection points used will be the inflection points specifically used for the collapse values. Note that these inflection points may not behave exactly in the same way as the capacity values. The exact behavior of these inflection points should be separately checked for the specific "real" data run.

3. Leakage Value

* Average together the tabulated leakage values of all the area defense ships.
* Next, multiply this value by the intercept factor. This factor corrects the leakage for reduced intercept possibilities due to reduced detection range.
* Average together the leakage values for the ships without area defense systems. The correction for intercepts is not made to this group of ships.
* Average together the leakage numbers from these two groups to obtain one leakage number. This should be a "weighted average:" if there are five times as many area defense ships as there are ships

without area defenses, the leakage value for area defense ships should be given five times the weight in this averaging process.

* Multiply by the ASCM difficulty factor. This factor was discussed above and is the relative difficulty *of destroying* the particular type of ASCM by the composite defenses (point and area) of the defending force. This factor is estimated by the operator based on the P-K of the six of defensive systems mounted by the defending force.
* Divide by the layer factor. This factor was discussed above and is the approximate number of layers of defending systems which the ASCM must penetrate. This factor is estimated by the operator based on the number of ships in the defending force and their formation.

4. <u>Extracting Results</u>

With the above values determined for the formation, the characteristic hit percentage curve per ASCM can be generated. With this curve, the hit percentage of every ASCM is known. The program SUMS simply takes the cumulative hits over each missile to generate the results.

For example, suppose the final values generated by the SUMS process for the formation gives a leakage value of 5%, a capacity value of 9, and a collapse value of 19. For the first 9 ASCM, the number of hits would be the leakage

value multiplied by the number of ASCM; in this case, 0.45 hits.

For the 10th ASCM, the percentage jumps to the sloped section of the curve (on Figure 10, the sloped section C-D). The 10th missile would have a hit percentage of 10%, and would thus on average cause an additional 0.1 hits. If the attack consisted of 10 ASCMs, the total hits would then be (0.45 + 0.10 = 0.55). If there was an 11th ASCM, the curve would indicate a hit percentage of 20% so it would be worth an additional 0.2 hits, bringing the total for 11 ASCMs to 0.75 hits. This procedure is repeated until the hits generated by all the missiles in the attack are summed.

Several other factors can be estimated from the number of ASCM in the attack and the number of hits.

ROUNDS EXPENDED: Area defense missile rounds fired can be estimated by multiplying the number of incoming ASCMs in the attack by the "rounds fired per missile" value in Table 14, using the P-K and number of intercepts in the attack.

ROUNDS DESTROYED: Area defense rounds destroyed may be estimated by determining the number of magazines destroyed per missile hit, assuming a uniform distribution of hits; and estimating the remaining average number of rounds in the magazines.

AREA DEFENSE BATTERIES REMAINING: Taking the total number of area defense batteries, and dividing them by the (number of ships times three) will give a serviceable estimate. A similar procedure can be used for self-defense batteries.

5. Testing

Table 16 demonstrates three test runs which compare the results of the LASMADS model to the results of the SUMS model. Case 1 is a six-ship U.S. CVBG; Case 2 is a ten-ship U.S. CVBG; Case 3 is a six-ship Soviet battle group. The correlation between LASMADS and SUMS is very good throughout the range of number of attacking ASCMs. This demonstrates that it is possible to approximate closely the results of a LASMADS run using the SUMS model and firepower indexing of ships. In addition, there were significant computer time savings; 1000 replications of each of the battle group series took approximately 10-50 seconds (depending on number of missiles in the attack) using LASMADS. SUMS ran the entire sequence of ten attacks in less than three seconds.

It should be emphasized that SUMS will run well only in "average" types of cases, i.e., cases that are consistent with the LASMADS model structure. Strange formations or other unusual initial conditions will yield anamolous result. The object of running SUMS was to demonstrate that the program could be successful under a given set of conditions. Since the numbers used are all estimates, there was no great effort

TABLE 16

TEST RESULTS: LASMADS vs SUMS

Case 1	NSHIPS = 6	1-2-2-7-8-9	TIMINT = 4.0
Case 2	NSHIPS = 10	1-2-3-4-5-6-7-8-9	TIMINT = 4.0
Case 3	NSHIPS = 6	17-18-18-16-21-22	TIMINT = 4.0

	1		2		3	
ATTACK	LASMADS	SUMS	L	S	L	S
10	.51	.53	.03	.09	.19	.21
20	2.43	2.08	.10	.18	2.14	1.19
30	4.86	4.57	1.38	.78	4.11	3.02
40	7.95	7.50	2.47	2.07	6.64	5.53
50	11.83	11.46	3.61	3.63	10.55	8.70
60	16.69	16.25	5.53	5.47	14.68	12.55
70	23.93	21.88	7.37	7.58	20.00	17.06
80	31.96	28.35	9.78	9.97	23.39	22.24
90	40.52	35.65	12.50	12.64	34.26	28.09
100	49.21	43.78	16.27	15.58	40.15	34.61

taken to verify some of the multiplicative factors or to pin down exactly some of the values used in the algorithms. In particular, the TIMINT inflection points and the ASCM difficulty factors should be worked out more precisely using classified data. A detailed determination of these factors would involve running several representative formations and single ships in base case scenarios, varying TIMINT, to verify the threshold-linear model estimated in this paper and to determine the inflection point values.

V. SINGLE VALUE FIREPOWER INDEXES AND LANCHESTER EQUATIONS

The final form of the values given for the ships is excellent for the purpose of a detailed model of the result behavior of the ship under an attack. However, it is not in a format condusive to Lanchester equation applications.

This can be rectified by some assumptions and mental gymnastics. First, the range of the values (the 0.1 - 1000.0 seconds TIMINT-specified values) could be eliminated by assuming a TIMINT based on the expected opposition. The TIMINT could be based on equipment capabilities leavened with command and control considerations. For example, open source literature gives the TIMINT of launch of the Harpoon in canister launcher at, say, 5.0 seconds. With an entire canister emptying at only 20 seconds, it would not be a broad assumption to assume that TIMINT would be maintained even if many ships were firing simultaneously, i.e., that one ship's launch would be tacked on to the end of the others. By pinning down a number for TIMINT, a capacity number can be determined for each ship.

The capacity number could alternately be treated as an estimate of the "life" of the ship, and subject to attrition. This idea is similar to the way that army firepower indexes are used. A given attack would then cause a given percentage degradation to the capacity of the ship. Or, the capacity

value might be considered as a threshold, below which tolerable damage is sustained (or, perhaps, insignificant damage), and above which progressively larger amounts of damage are sustained.

In any event, when tracking these "engagements" in such a firepower exchange model, ammunition must be accounted for. AAW ammunition is limited and subject to destruction, limiting the sustainability of any defensive force. ASCM ammunition is even more limited. A surface ship essentially disarms itself when it launches its SSM attack.

The application of firepower indexing to naval ships opens the way to the use of Lanchester equations which remain as a fruitful avenue of future work.

VI. CONCLUSIONS

The objectives of this research were to investigate the application of firepower indexes to naval units and to integrate these values into a deterministic model which could predict battle results. Within the limits of unclassified numerical inputs applied to generic systems, this aim was accomplished.

First, a method of determining a five valued AAW firepower index for all naval ships was developed. These numbers provide a potentially powerful operational tool. When confronted with a particular threat, an operational commander can make a reasonable estimate of the adequacy of his force to defeat that threat. If found to be inadequate, he can estimate the amount of additional firepower required for the situation. He can estimate the contribution made to his defenses by each vessel, and thus can better judge the risks involved in detaching ships from one duty to another. Consequently, the allocations of forces and campaign planning can proceed with a better foundation for balancing the line between concentration of force and economy of force.

Second, using these firepower indexes, a deterministic model (SUMS) was created which can provide rapid estimates of force losses and ammunition expended and destroyed when

a force is subjected to attack. This provides attrition estimates for the operational planner, the complement to firepower indexing in the planning process. Not only does the planner have an estimate of the firepower needed to meet an attack, he has an estimate of his resulting losses and an estimate of the remaining firepower of the force. Allowing for losses can ensure that the force will be sufficiently strong to sustain itself in the threat area for a sufficient time to carry out its mission. Such estimates must be incorporated into any planning process. The use of firepower indexes and the SUMS model provides a powerful tool towards that end.

A serendipitous result of the investigation into firepower indexing was a better understanding of the aggregated dynamics of the air defense problem. Several things were learned: that there is a cooperative nature between area and point defense; that the installation of area and point defenses must be balanced for either one or the other to reach full potential; and that tailoring the firing doctrine to the individual ship can result in significant performance gains.

The discovery that U.S. ships cannot reach the full potential of their air defense systems for lack of point defenses is disturbing; the discovery that the Soviet ships have an almost optimal balance between area defense systems and point defense systems is equally disturbing, and indicates

that the Soviets have more successfully matched the actual design of their ships to analytical optimums.

This research has not provided the "final answer" to the question of naval use of firepower indexes. Indeed, it has only suggested a methodology, an approach to the problem. There is ample room for expansion on the theme, with the possibility of the gain of an important new analytical tool.

APPENDIX A

SUGGESTIONS FOR FURTHER WORK

As mentioned in several places in the paper, there are many areas remaining where fruitful work can be accomplished in the area of firepower indexing, and the use of firepower indexing. In addition, some of the tools used in the course of this reasearch (the LASMADS simulation and the SUMS model) have room for improvement. The following are some suggested areas where work could be accomplished.

1. "REAL" VALUE DETERMINATION

The numbers generated in this study were generic estimates based on unclassified inputs. Consequently, effort was used on the models, and not on the numbers generated. Determination of firepower index values, inflection point values, ASCM difficulty factors, intercepts factors, and the entire range of figures used is an area for development and application.

2. INDEPENDENCE OF FIRST ORDER EFFECTS

The final model used in SUMS was a multiplicative model--a number is multiplied by another to reach a result. For example, in the "Leakage" calculation, the final leakage is determined by multiplying an intercepts factor, a "difficulty" factor, and a formation or "layers" factor.

The use of a multiplicative model assumes that these factors are independent, and that varying one will not affect the value of the other. There are several places where this type of model and assumption are used. This assumption could be investigated further.

3. COMPARISON OF THE RESULTS OF LASMADS WITH MORE DETAILED SIMULATIONS

To meet the objectives specified for LASMADS, several assumptions were made, such as the suppression of geometric effects, the effect of crossing shots on the value of a ship, and others. These assumptions were assumed to have a small effect on the actual combat results of the simulation. This assumption could be verified by comparing the results of the LASMADS simulation with larger, more detailed simulations, including war games.

4. REFINEMENT OF THE LASMADS MODELS

LASMADS includes a variety of smaller models within the simulation. For example, there is the targeting model, the point defense model, the damage model, and others. Adjustment of the LASMADS program to include an option which would allow defending ships to only engage ASCM targeted against ships in the same plane as the defending ship would improve the simulation results with regard to low altitude subsonic missiles. Throughout the simulation, the models were either simplified to an extreme, incorporated some

sweeping assumptions, or made "generic" to suppress individuality. There is room within each of these models for improvements. The establishment of better and more specific models would contribute to the accuracy of the process of determining the firepower index numbers.

5. COMBINATORIAL EFFECTS OF FORCES

Only basic work was performed in investigating the effects of adding forces together. It was shown that one plus one did not equal two: that there were factors of formation, weapons types, command and control, the others which impacted the net value of an aggregate of individual units. This would be an important field for further work.

6. DECOYS, COMMAND AND CONTROL, MISSILE PENETRATIONS, AND OTHERS

Within the LASMADS simulation, there were several additional options which could be invoked, such as the use of decoys, command and control problems, and others. The effect of using these options on the results of the engagement were not explored, and not incorporated in the final SUMS model. Investigation of these factors and incorporation of them into the SUMS model would be important for operational planning.

7. FIREPOWER DEGRADATION WITH DAMAGE

The final output of the SUMS model is number of hits. The distribution of hits, and number of systems and ammunition destroyed, can be inferred. However, the net effect of

this damage on the power of the force was not explored, for lack of a better and more ship-specific damage model. One of the eventual outputs of SUMS should be not only hits but remaining firepower. This work would be an important addition to the SUMS model.

8. TAILORING INDIVIDUAL SHIPS

Throughout the study a certain level of performance was allowed for each system. It was assumed that the crew would operate to the efficiency of the systems.

However, as noted in the introduction, there are insufficient numbers on board a naval unit to use the law of large numbers as a rationale to average out the unit performance. Wide variation of unit capabilities will result from training, manning levels, and leadership differences. The effect of these differences on the firepower index of a ship would bear further study and be applied in realistic planning.

9. ASW AND ASuW FIREPOWER INDEXES

This study confines itself to determining firepower index for surface ships when under attack by anti-ship cruise missiles. As noted in the introduction, similar firepower indexes could be developed to represent the combat capability of a ship in the other warfare areas. In addition, the extension of the ASCM firepower index to attack by manned aircraft is needed.

```
C        TO LOOP GO TO 225
C     IF GO DIRECTLY TO INITIALIZATION SECTION, GO TO LINE 215
C     ***********************************************************************
C     *                                                                     *
C     *                       L.A.S.M.A.D.S                                 *
C     *                                                                     *
C     *     LINEAR ANTI-SHIP MISSILE AREA DEFENSE SIMULATION                *
C     *                                                                     *
C     *   ONE DIMENSIONAL ANTI-SHIP CRUISE MISSILE DEFENSE MODEL            *
C     *                                                                     *
C     *   MODEL DESIGNED AS AN APPROXIMATION OF GROUPED DEFENSES VS         *
C     *   ASCM ATTACKS TO DETERMINE VALUE OF TIME AND FORCE [illegible]     *
C     *   AUGUST 1985  A.C. ZIMM LCDR USN                                   *
C     ***********************************************************************
C
C
C
C
C     LIMITATIONS OF THE MODEL:
C
C        ALL SHIPS MUST BE LOCATED WITH AN X-POSITION [illegible] THAN ZERO
C        SHIPS MUST BE SEPARATED BY AT LEAST 0.1 NM
C        MAXIMUM NUMBER OF SHIPS = 20 WITH [illegible]
C           AREA [illegible] MISSILE CHANNELS AND NO MORE THAN [illegible] SELF-
C           DEFENSE SYSTEMS ABLE TO OPERATE ON A SINGLE [illegible]
C        NO CROSS MAGAZINE MISSILE ASSIGNMENTS
C        SHIPS ARE CONSIDERED TO HAVE [illegible]
C           DEFENSIVE ASPECT - TIME LIMITATIONS WILL NOT ALLOW THIS TO
C           CHANGE TO ACCOUNT FOR AMMUNITION [illegible], CAPACITY [illegible] OTHER FACTORS
C        MAXIMUM OF [illegible] ATTACKING MISSILES
C        CRUISE MISSILE ATTACK ARRIVES FROM A SINGLE [illegible] ONLY
C        TWO DIFFERENT AREA DEFENSE MISSILES ARE ALLOWED, WITH DIFFERING
C           RANGES AND KILL PROBABILITY [illegible] VELOCITY
C        MISSILES ARE DETECTED WITH 100% PROBABILITY AT [illegible] RANGE.
C        SHIPS CANNOT [illegible] BEYOND [illegible] INDIVIDUAL [illegible]
C        ALL SHIPS [illegible] WITH THE SAME [illegible] EVALUATION
C
C
C
C           EXPLANATION OF TERMS IN THE [illegible]:
C
C      ASCM(I,20) [illegible] PERCENTAGE OF I-TH [illegible]
C      AVAIL      BATTERY AVAILABILITY [illegible]
C      ASSET      ASSESSMENT TIME FOR [illegible]
C      ATTACK     NUMBER OF ASCM IN [illegible]
C      AXIS(20)   POSITION OF THE I-TH SHIP [illegible]
C                      [illegible], I-TH [illegible]
C      [illegible]  NUMBER OF BATTERY [illegible]
```

```
C     C3DEGP     PERCENTAGE OF HANDOFFS EXPERIENCING CCC DEGRADATION
C     C3DTIM     MAX TIME OF CCC DEGRADATION
C     CCCDEG     =1, COMMAND AND CONTROL DEGRADATION OPTION SELECTED
C     CMCLAS     ASCM CLASS, AS PER PK
C     CMDATA(210,3) FOR I-TH MISSILE (MAXIMUM OF 210 MISSILES)
C                      I,1 = INITIAL RANGE
C                      I,2 = CURRENT RANGE
C                      I,3 = IMPACT TIME ON TARGET
C     CMRES(210,2) ASCM RESULTS OF ATTACK FOR I-TH MISSILE
C                      I,1 = WEAPON SYSTEM WHICH KILLED ASCM (0=MISSILE HIT)
C                      I,2 = SHIP WHICH DESTROYED ASCM OR WAS HIT BY ASCM
C     COSRO      =1, SELECTED OPTION ALLOWING 0 CYCLE TIME FOR ECM DEFENSE
C     CMPOS      CURRENT ASCM POSITION
C     CMVEL      ASCM VELOCITY
C     CUMH(210)      CUMULATIVE HITS TO I-TH MISSILE
C     CUMP(210)      CUMULATIVE PERCENTAGE OF HIT TO I-TH MISSILE
C     CYCLE(6)   CYCLE TIME BETWEEN END OF ONE ENGAGEMENT TO LOCK-ON
C                   FOR NEXT ENGAGEMENT, FOR I-TH WEAPON SYSTEM CODED
C                  AS IN PK
C     DELAY      =1, DELAY OPTION SELECTED
C     DFIREF(6)  NUMBER OF ROUNDS FIRED BY I-TH CLASS WEAPON
C     DT         COMPUTED HANDOFF TIME DELAY
C     EXCS       DECOY RADAR CROSS SECTION
C     ENVEL(2,3) FIRING RANGES FOR I-TH CLASS SAM (MIN,SALVO,MAX)
C     F          NUMBER DIVISOR OF REPETITIONS
C     FCCN       INTERMEDIATE STORAGE ARRAY FOR FIRCON (P...-...)
C     FCNFF      TOTAL NUMBER OF FIRE CONTROL CHANNELS REMAINING
C     FILL       NUMBER OF BEGINNING BATTERY ON A SHIP
C     FIRCON(150,3)  FIRE CONTROL BATTERIES, SORTED FROM MAX TO MIN
C                        GEOGRAPHIC RANGE, FOR I-TH BATTERY
C                        I,1 = SHIP OWNING THIS BATTERY
C                        I,2 = TIME DESTROYED BY MISSILE HIT
C                        I,3 = MAGAZINE SERVING THIS BATTERY
C     FIRE        NUMBER OF MISSILES FIRED AT A TARGET, 1 OR (SALVO=) 2
C     FIRED       NUMBER OF MISSILES FIRED OR ENGAGEMENTS PER WEAPON TYPE
C     FIRENV(20,2) FIRING RANGE OF (SHIP,RANGE) SORTED BY RANGE
C     FIRERS      NUMBER OF SHIPS WITH AREA DEFENSE SAM SYSTEMS
C     FLAG,N,O,P  INTERMEDIATE STORAGE VALUES
C     HITOF      TOTAL HITS ON ALL SHIPS
C     HITS(20)   NUMBER OF HITS ON THE I-TH SHIP
C     HTOTAF(20)   TOTAL HITS ON THE I-TH SHIP
C     HVTPER     PERCENTAGE OF MISSILES EXPERIENCING AUGMENTED TARGETING
C     HVTVUL     FACTOR OF VULNERABILITY OF HIGH VALUE TARGETING
C     IX,IKT     SEED NUMBERS FOR LL-RANDOM
C     KTOTAF(20)     TOTAL KILLS BY THE I-TH SHIP
C     M          MISSILE NUMBER
C     MAG(40)    NUMBER OF ROUNDS IN I-TH MAGAZINE
C     MAGDES     TOTAL AIR DEFENSE ROUNDS DESTROYED BY ASCM HITS
```

```
C     MAGNR       NUMBER OF THE MAGAZINE SERVING THE ENGAGED BATTERY
C     MAGOP(40)   INDICATOR OF MAGAZINE STATUS OF THE I-TH MAGAZINE
C                        =1, MAGAZINE OPERATIONAL
C                        =0, MAGAZINE DESTROYED OR EMPTY
C     MAGREM      TOTAL AIR DEFENSE ROUNDS REMAINING
C     MAGTOT      TOTAL NUMBER OF MAGAZINES
C     MAXENV      FARTHEST OUT FIRING ENVELOPE
C     MTARG       TARGET SHIP OF I-TH MISSILE
C     NBAT        NUMBER OF AREA DEFENSE SAM BATTERIES
C     NRSDS       NUMBER OF SELF-DEFENSE SYSTEMS
C     NSHIPS      NUMBER OF SHIPS IN THIS SCENARIO RUN
C     OADEG       OFF-AXIS DEGRADATION OF PK OF AREA DEFENSE SAM
C     ONET(2)     NUMBER OF SINGLE SHOTS FOR AREA DEFENSE MISSILES
C     PEN         =1, ALLOWS A DESIGNATED PERCENTAGE OF ASCM TO PENETRATE
C                        TO POINT DEFENSES WITHOUT AREA DEFENSE ENGAGEMENT
C     PENPER      PERCENTAGE OF MISSILES ALLOWED TO PENETRATE
C     PER1-6      INTERMEDIATE STORAGE FOR OUTPUT
C     PK(6,3)     PROBABILITY OF KILL,(WEAPON,ASCM)
C                    WEAPON=1  LONG RANGE AREA DEFENSE SAM
C                          =2  INTERMEDIATE RANGE AREA DEFENSE SAM
C                          =3  SHORT RANGE SELF DEFENSE MISSILE
C                          =4  MEDIUM CALIPER GUN
C                          =5  CIWS GUN
C                          =6  ELECTRONIC COUNTERMEASURES
C                    ASCM  =1  LOW ALTITUDE ASCM SUBSONIC
C                          =2  INTERMEDIATE ALTITUDE ASCM TRANSSONIC
C                          =3  HIGH ALTITUDE ASCM SUPERSONIC
C     RADAR        COOKIE-CUTTER RADAR RANGE
C     RAN          SEQUENCING VARIABLE FOR RETRIEVING RANDOM NUMBERS
C     RANGE(2,2)   MINIMUM AND MAXIMUM INTERCEPT RANGE FOR I-TH CLASS SAM
C     RANR         RANDOM NUMBER
C     RCS(20)      CROSS SECTION ARRAY TO RANDOMLY SELECT MISSILE TARGET
C     RREM(20)     AD ROUNDS REMAINING TO THE I-TH SHIP
C     SALVO        WHEN FIRING SALVO OF MISSILES, TIME BETWEEN SHOTS
C     SAMVEL       SAM VELOCITY
C     SDREF        TOTAL NUMBER OF SELF-DEFENSE BATTERIES REMAINING
C     SDTIME       BATTERY AVAILABILITY TIME FOR SELF-DEFENSE SYSTEMS
C     SDTOT        TOTAL NUMBER OF SELF-DEFENCE POINT DEFENSE SYSTEMS
C     SELDEF(120,4)   SELF DEFENSE WEAPON SYSTEMS, FOR I-TH SYSTEM
C                    I,1 = SHIP OWNING THE BATTERY
C                    I,2 = WEAPON TYPE CODE
C                    I,3 = AVAILABILITY CODE
C                    I,4 = NUMBER ENGAGEMENTS REMAINING IN THE MAGAZINE
C     SHCLAS(20)  INPUT SHIP CLASS - THE PROGRAM AUTOMATICALLY CAN HANDLE:
C                  1  US CARRIER      10 TICONDEROGA (WITH VLS)
C                  2  CGN 38          11 KIROV
C                  3  CG 26           12 KIROV MOD          20 KYNDA
C                  4  CG 16           13 KIEV               21 [illegible]
```

```
C                    5   DDG 2            14 BLK COM 1         22 KRIVAK
C                    6   DDG37            15 SOVREMENNYY       23 AUXILIARY W/ PU
C                    7   DD 963           16 UDALOY
C                    8   FFG 7            17 MOSKOVA
C                    9   FFG 1052         18 KARA
C                   99   DECOY            19 KRESTA II
C       SHENV(20,3)  FOR THE I-TH SHIP
C                     I,1 = MINIMUM RANGE TO FIRE AREA DEFENSE SAM
C                     I,2 = RANGE THRESHHOLD TO FIRE SALVE OF 2 SAM
C                     I,3 = MAXIMUM RANGE TO FIRE AREA DEFENSE SAM
C       SHIPID       NUMBER OF SELF DEFENSE SYSTEMS AVAILABLE TO I-TH SHIP
C       SHKILF       NUMBER OF SHIPS EXPERIENCING FIREPOWER KILL
C       SHWEPS(20,6)  INVENTORY OF NUMBER OF WEAPONS,(SHIP,WEAPON TYPE)
C       SKIP         PRINTOUT OPTION SELECTOR
C       SLRBAT(140,3) SAM LONG RANGE BATTERY INFORMATION FOR I-TH BATTERY
C                    I,1 = NUMBER OF SAM FIRE CONTROL UNITS (I.E. #ENGAGE)
C                    I,2 = NUMBER OF MAGAZINES SERVING AD BATTERIES
C                    I,3 = NR OF FIRST BATTERY IN FIRCON ARRAY
C       SOVIET       INDICATOR OF NATIONALITY OF SHIPS, 1=SOVIET,OTHER=U.S.
C       SPOS(20)     GEOGRAPHIC POSITION OF THE I-TH SHIP OR DECOY
C       STYPE(20)    FOR I-TH SHIP, TYPE OF WEAPONS
C                     0 = SELF DEFENSE WEAPONS ONLY
C                     1 = LONG RANGE SAM
C                     2 = INTERMEDIATE RANGE SAM
C                     3 = DECOY
C       SYSKIF(6)    NUMBER OF KILLS BY I-TH CLASS WEAPON
C       T            CURRENT TIME
C       TARGET       TARGET SHIP NUMBER
C       TARTOF(20)   TOTAL MISSILES TARGETED ON THE I-TH SHIP
C       TIMINT       TIME INTERVAL BETWEEN ASCM
C       TINTER       TIME OF INTERCEPT
C       TNT          TIME WHEN THE ASCM WILL ENTER THE NEXT WEAPON ENVELOPE
C       TRACK       TIME REQUIRED FROM INITIAL DETECTION TO READY FOR FIRST
C       TWCT(2)     NUMBER OF SALVOES FOR AREA DEFENSE MISSILES
C       WAVSEP      TIME SEPARATION BETWEEN FIRST AND SECOND WAVE
C       XCS(20)     SHIP RADAR CROSS SECTION IN SQ METERS
C                    ON HIGH VALUE UNITS
C
C       ** REMAINING VALUES ARE TEMPORARY STORAGE VALUES OF [illegible] VALUES
C          STORED IN SPECIFIC INTEGER OR REAL VARIABLES **
C
C
C
C
C
      REAL XCS(20), RCS(20), [illegible]AVEL(3),PK(6,3),RANG(2,2), [illegible]VEL([illegible])
      REAL SAMVOL, FIRENV(20,2), SPOS(20), MAXENV, TI[illegible], T, X(2), [illegible]
      REAL CMEATA(210,3), SHENV(20,3), CMFOS, TINTER, CYCLE(6), ASN[illegible]
```

```
      REAL SALVO, INT, SOTIME(120), RANK, CMVOL,C3DEGP,     JADEG
      REAL DXCS, AOTIME(80), YY, HVTPER, HVTVOL, C3DTIM,DT
      REAL F, FTOTAF(20), TARTOF(20),KTOTAF(20), HITOF, SHKILF
      REAL FCREF, SOREF, DFIREF(6), SYSKIF(6), ASCMF(210), PENPER
      REAL MACREM, MAGDES, RADAR, TRACK, UNET(2), TWOT(2)
      REAL PER1, PER2, PER3, PER4, PER5, PER6, RESULT(6,3,15)
      REAL NRES(6,3,15),COMM(210),COMP(210),WAVSEP,YYY,KREM(20)
C
C
C
      INTEGER NSHIPS, ATTACK,COSRO,IX, IXT, MTARG(210), I,J,K,M,N,O,P
      INTEGER CMCLAS, STYPE(20), SERBAT(20,3), FLAG, FIRERS, NJAT
      INTEGER FIRCON(80,3), MAG(40), BAIRY, FIRE, SFLDEF(140,4),PEN
      INTEGER SHIPTD(20,2),TARGET,FILE, NKSDS, FIRED(6), CMRES(210,2)
      INTEGER SHCLAS(20), FCON(80,3), FC, MZ, SC, SSO, SFC, MAGTOT
      INTEGER SOTOT,RAN,NS, HITS(20), MAGOP(40), MR, I1, MAGNR
      INTEGER SHWEPS(20,6), NUM(210), AOG, REPS, R, HITOT, HICTAL(20)
      INTEGER FCREM, SOREM, KTOTAL(20), TARTOT(20), ADFIRE, ADREM
      INTEGER SHKILL,WAVE,NSHIP,  SYSKIL(6), TARG(20), DFIRED(6)
      INTEGER ASCMH(210),A(120),S(4),AA,SS, AXIS(20),TT,MAGASN(40)
      INTEGER MAGCAP, MAGRT, MAGORT, ONE(2), TWO(2),Z,KNDREM(20)
      INTEGER SOVIET, DELAY, CCODEG, SKIP
C
      REAL*4 RAND(1000),GRES1(80),GNUM(120),GRES2(80),GRES3(120)
C
      DO  3 I=1,120
          A(I)=I*I
          GNUM(I)=FLOAT(I*I)
    3  CONTINUE
       DO  4 I=1,3
          S(I)=1
    4  CONTINUE
C                        BOTTOM OF LOOP +2255 LINE 2477
C     DO 7 AA=1,2
C     AA=3
C     TT=11
C     DO 5 SS=1,6
C     DO 6 TT=5,5
C     INITIALIZATION OF OUTPUT STORAGE ARRAYS
C
      HITOT=0
      FCREM=0
      SOREM=0
      ADFIRE=0
      SOFIRE=0
      SHKILL=0
      ADREM=0
      TWOT(1)=0.0
```

```
      TWOT(2)=C.0
      UNET(1)=C.0
      UNET(2)=C.0
      MAGRT=0
      MAGDKT=C
C
      DO 10 I=1,20
           HTOTAL(I)=0
           KTOTAL(I)=0
           TARTCT(I)=0
           RNDREM(I)=0
           KREM(I)=0.C
           MAG(I)=0
           MAG(I+20)=0
10    CONTINUE
C
      DO 20 I=1,6
            SYSKIL(I)=0
            DFIRED(I)=0
20    CONTINUE
C
      DO 30 I=1,210
            ASCMH(I)=0
            NUM(I)=I
            CUMF(I)=0.0
            CUMP(I)=0.0
30    CONTINUE
C
C
C
C     INITIALIZE SEED AND RANDOM NUMBERS
C
      IXT=1
      RAN=1
      CALL RCLL(RAN,RAND,IXT)
C
C     ****************************************************************
C
C                       INITIALIZATION SECTION
C     USERS INPUT THE INFORMATION FOR THEIR TRIAL AS FOLLOWS:
C     ****************************************************************
C
C
C     INDICATE NUMBER OF REPLICATIONS DESIRED
      REPS =50C
      F=FLOAT(REPS)
      DO 40 K=1,REPS
C
```

```
C     * IF DEFENDING SHIPS ARE SOVIET, ENTER '1'; OTHERWISE ENTER 0
        SOVIET=0
        IF(AA.GT.2 )SOVIET=1
C
C
C     * INPUT NUMBER OF SHIPS AND DECOYS (TOTAL) USED IN THIS RUN
        NSHIPS = 5
C
C
C     * ENTER THE NUMBER OF ATTACKING MISSILES
        ATTACK = 100
        ATTACK=  100
C       ATTACK = 10.0*FLOAT(AA)
C       IF(AA.GT.1)ATTACK=45
C
C
C     * ENTER THE CLASS OF THE ATTACKING ASCM
        CMCLAS = 2
C
C
C     * ENTER THE TIME INTERVAL BETWEEN INCOMING ASCM, SECONDS
        TIMINT = 0.1
C       IF((AA.GT.1))TIMINT=1000.0
C       TIMINT=( 3.01*(FLOAT(TT)))- 3.0
C       IF(TT.EQ. 2)TIMINT=1000.0
C       IF  (TT.EQ.2)TIMINT=1000.0
C
C     * TO INVOKE RADAR ACTIVATION TIME DELAY, SET DELAY=1; OTHERWISE 0
        DELAY = 0
C
C
C     * IF DELAY=1, INDICATE DELAY TIME
        DT=0.0
C
C
C     * TO INVOKE C3 DETECTION, ASSIGNMENT AND FIRING HANDOFF DELAYS
C          SET CCCDEG=1; OTHERWISE 0
        CCCDEG=0
C
C
C     * IF CCCDEG=1, ENTER DECIMAL OF INTERACTIONS INFLUENCED
        C3DEGP= 0.00
C
C
C     * AMOUNT OF DELAY WILL BE A UNIFORM RANDOM NR 0.0 TO C3DTIM SECS
        C3DTIM=00.0
C
C
C     * TO ALLOW PENETRATION OF AREA DEFENSES WITHOUT SAM ENGAGEMENTS,
C          SET PEN = 1
           PEN = 1
C
C
C     * INDICATE PERCENTAGE OF MISSILES ALLOWED PEN (I.E. 0 TO 1.0)
           PENPER= 1.00
C
C
C     * TWO WAVE ATTACK, ENTER 2; ONE WAVE ATTACK ENTER 1
```

```
      WAVE = 1
C
C     * IF TWO WAVE ATTACK IS USED, ENTER TIME OF SEPARATION, SECONDS
      WAVSEP = 00.0
C
C     * ENTER 1 IF TARGETING SPECIFIC HVT HULLS POSSIBLE; OTHERWISE 0
      AUG = 1
C
C     * ENTER PERCENTAGE OF MISSILES WITH POSS SPECIFIC HVT TARGETING
      HVTPER =1.00
C
C     * ENTER DEGREE OF AUGMENTATION (IE PERCENT OF POSS IN TARG LIST)
      HVTVOL =1.00
C
C     * ENTER 1 IF MULTIPLE SIMULTANEOUS ECM ENGAGEMENTS POSS; ELSE 0
      COSRO = 0
C
C     * ENTER COOKIE-CUTTER RADAR RANGE OF RAID DETECTION
C        (IF ECM ENVIRONMENT, ENTER BURNTHROUGH RANGE;
C         IF CLEAR ENVIRONMENT, ESTIMATE SUGGEST FOR CMCLAS 1 USE 22.0
C                                        CMCLAS 2 OR 3 USE 190.0)
      RADAR=180.0
C     IF(SS.EQ.2) RADAR=170.0
C     IF(SS.EQ.3) RADAR=180.0
C     IF(AA.EQ.2)RADAR=10.00
C     IF(AA.EQ.3)RADAR=18.0
C
C     * ENTER INITIAL TRACKING TIME BEFORE FIRM TRACK AND LOCK-ON,
C          IN SECONDS
      TRACK=30.0
C
C     * ENTER CLASS OF EACH SHIP/DECOY - IN ORDER OF VALUE (HVT-TOP)
      SHCLAS( 1) = 9
      SHCLAS( 2) = 9
C     IF(AA.EQ.2)SHCLAS(1)=3
C     IF(AA.EQ.3)SHCLAS(1)=4
      SHCLAS( 3) = 9
      SHCLAS( 4) = 9
      SHCLAS( 5) = 9
      SHCLAS( 6) =16
      SHCLAS( 7) =17
      SHCLAS( 8) =18
      SHCLAS( 9) =19
      SHCLAS(10) = 20
      SHCLAS(11) = 21
      SHCLAS(12) = 22
      SHCLAS(13) = 9
      SHCLAS(14) = 7
```

```
      SHCLAS(15) = 9
      SHCLAS(16) = 0
      SHCLAS(17) = 0
      SHCLAS(18) = 0
      SHCLAS(19) = 0
      SHCLAS(20) = 0
C
C    * ENTER POSITION OF EACH SHIP OR DECOY, IN MILES, > 0.0
C    * TWO SHIPS CANNOT OCCUPY THE SAME LOCATION
C    * MISSILE MAX RANGE ENVELOPES SHOULD NOT COINCIDE
      SPOS( 1) =   15.0
      SPOS( 2) =   20.1
C     IF(SS.EQ.2)SPOS(2)=100.0-(5.01*FLOAT(IT))+5.01
      SPOS( 3) =  15.12
      SPOS( 4) =  11.0
      SPOS( 5) = 16.6
      SPOS( 6) = 14.0
      SPOS( 7) = 24.0
      SPOS( 8) =  9.0
      SPOS( 9) = 7.5
      SPOS(10) = 44.0
      SPOS(11) = 7.0
      SPOS(12) = 15.0
      SPOS(13) = 21.1
      SPOS(14) = 25.5
      SPOS(15) = 33.0
      SPOS(16) = 0.
      SPOS(17) = 0.
      SPOS(18) = 0.
      SPOS(19) = 0.
      SPOS(20) = 0.
C
C    * IF THE SHIP IS TO THE LEFT OF AXIS, ENTER 0
C    * IF THE SHIP IS ON THE ATTACK AXIS, USE 1
C    * IF THE SHIP IS TO THE RIGHT OF AXIS, ENTER 2
C    *       NOTE: HVT IS ALWAYS ON THE AXIS
      AXIS( 1) = 1
      AXIS( 2) = 1
C     IF(AA.EQ.2)AXIS(2)=0
C     IF(AA.EQ.3)AXIS(2)=1
      AXIS( 3) = 0
      AXIS( 4) = 1
      AXIS( 5) = 1
      AXIS( 6) = 2
      AXIS( 7) = 1
      AXIS( 8) = 0
      AXIS( 9) = 1
      AXIS(10) = [illegible]
```

```
      AXIS(11) = 1                                                      AD 04330
      AXIS(12) = 1                                                      AD 04340
      AXIS(13) = 0                                                      AD 04350
      AXIS(14) = 1                                                      AD 04360
      AXIS(15) = 2                                                      AD 04370
      AXIS(16) = 1                                                      AD 04380
      AXIS(17) = 1                                                      AD 04390
      AXIS(18) = 1                                                      AD 04400
      AXIS(19) = 1                                                      AD 04410
      AXIS(20) = 1                                                      AD 04420
C                                                                       AD 04430
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCAD 04440
C                                                                       AD 04450
C     OUTPUT OPTION SELECTION                                           AD 04460
C                                                                       AD 04470
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCAD 04480
C                                                                       AD 04490
C    *  IF SUMMARY RESULTS ARE DESIRED, SET SKIP=1                      AD 04500
C    *  IF SUMMARY RESULTS AND INDIVIDUAL MISSILE OUTPUT DESIRED,       AD 04510
C                                             SKIP=2                    AD 04520
C    *  IF SUMMARY RESULTS AND INDIVIDUAL MISSILE OUTPUT AND MISSILE   AD 04530
C          HIT PERCENTAGE GRAPH DESIRED,      SKIP=3                    AD 04540
C    * ONLY COLLAPSE/SATURATION VALUES,       SKIP=4                    AD 04550
      SKIP=1                                                            AD 04560
C                                                                       AD 04570
C    ****************************************************************** AD 04580
C                                                                       AD 04590
C    THE FOLLOWING ENTRIES ARE STANDARD SET-UP PARAMETERS WHICH         AD 04600
C    MAY BE VARIED IF DESIRED                                           AD 04610
C                                                                       AD 04620
C    ****************************************************************** AD 04630
      CMVEL(1) = .15                                                    AD 04640
      CMVEL(2) = .378                                                   AD 04650
      CMVEL(3) = .062                                                   AD 04660
      CMVUL = CMVEL(CMCLAS)                                             AD 04670
      SAMVUL = .3788                                                    AD 04680
      IF(SOVIET.EQ.1)SAMVUL=.333                                        AD 04690
      PK(1,1) = .5                                                      AD 04700
C     PK(1,1)=1.0-(.1*FLOAT(II))                                        AD 04710
      PK(1,2) = .7                                                      AD [illegible]
      PK(1,3) = .4                                                      AD [illegible]
      PK(2,1) = .5                                                      AD [illegible]
C     PK(2,1)=1.0-(.1*FLOAT(II))                                        AD [illegible]
      PK(2,2) = .7                                                      AD [illegible]
      PK(2,3) = .4                                                      AD [illegible]
      PK(3,1) = .91                                                     AD [illegible]
      PK(3,2) = .75                                                     AD [illegible]
      PK(3,3) = .8                                                      AD [illegible]
```

```
      PK(4,1) = .2
      PK(4,2) = .1
      PK(4,3) = .05
      PK(5,1) = .7
      PK(5,2) = .6
      PK(5,3) = .4
      PK(6,1) = .5
      PK(6,2) = .5
      PK(6,3) = .5
      RANGE(1,2)=75.0
      RANGE(2,2)=25.0
      RANGE(1,1) = 2.5
      RANGE(2,1) = 2.5
      CYCLE(1) = 20.0
      CYCLE(2) = 20.0
      CYCLE(3) = 40.0-(5.0*FLOAT(CMCLAS))
      CYCLE(4) = 30.0
      CYCLE(5) = 30.0-(5.0*FLOAT(CMCLAS))
      CYCLE(6)=24.0
      IF(COSRC.EQ.1)CYCLE(6)=0.0
      ASSES = 10.0
      SALVO = 5.0
      JADEG = .15
      DXCS = 1200.0
C
C     ********** AUTOMATIC SHIP DATA ENTRY SECTION *****************
C
      FC = 1
      SD = 1
      IZ = 1
      FIRERS = 0
C
      DO 50 I = 1, NSHIPS
C
C  **************** EXPERIMENTAL SHIP
C
C
      IF (SHCLAS(I).NE.99)GO TO 45
      RCS(I)= 2000.0
      STYPE(I)=2
      FIRERS=FIRERS+1
      SHIPID(I,1)=1
      SHIPID(I,2)=50
      DO 45 J=1,1
          SFLEFT(50+J-1,1)=1
          SFLEFT(50+J-1,3)=1
          SDTIME(50+J-1)=0.0
 45   CONTINUE
```

```
      SELDEF(SC  ,2)=5
C     SELDEF(SC+1,2)=5
C     SELDEF(SC+2,2)=5
C     SELDEF(SC+3,2)=6
      SELDEF(SC  ,4)=3
C     SELDEF(SC+1,4)=3
C     SELDEF(SC+2,4)=3
C     SELDEF(SC+3,4)=10
      SD=SD+1
      SLRBAT(I,1)=4
      SLRBAT(I,2)=1
      SLRBAT(I,3)=FC
      FCON(FC  ,3)=MZ
      FCON(FC+1,3)=MZ
      FCON(FC+2,3)=MZ+1
      FCON(FC+3,3)=MZ+1
      MAG(MZ)=40
      MAG(MZ+1)=40
      MZ=MZ+2
      DO 44 J=1,4
         FCON(FC+J-1,1)=1
         FCON(FC+J-1,2)=1
         ADTIME(FC+J-1)=0.0
   44 CONTINUE
      FC=FC+4
C
      SHWEPS(I,1)=0
      SHWEPS(I,2)=3
      SHWEPS(I,3)=0
      SHWEPS(I,4)=2
      SHWEPS(I,5)=1
      SHWEPS(I,6)=1
C
      GO TO 50
   43 CONTINUE
C *********************************************** EXPERIMENTAL SHIP
C     **** CARRIER DATA
C
      IF (SHCLAS(I).NE.1)GO TO 50
      XCS(I)=4070.0
      STYPE(I)=0
      SHIPTD(I,1)=5
      SHIPTD(I,2)=50
      DO 55 J=1,5
         SELDEF(SD+J-1,1)=1
         SELDEF(SD+J-1,5)=1
         SDTIME(SD+J-1)=0.0
   55 CONTINUE
```

```
      SELDEF(SD  ,2)=3
      SELDEF(SD+1,2)=3
      SELDEF(SD+2,2)=5
      SELDEF(SD+3,2)=5
      SELDEF(SD+4,2)=6
      SELDEF(SD  ,4)=4
      SELDEF(SD+1,4)=4
      SELDEF(SD+2,4)=3
      SELDEF(SD+3,4)=3
      SELDEF(SD+4,4)=999
      SD=SD+5
C
      SHWEPS(I,1)=0
      SHWEPS(I,2)=0
      SHWEPS(I,3)=2
      SHWEPS(I,4)=0
      SHWEPS(I,5)=2
      SHWEPS(I,6)=1
C
      GO TO 50
C
C     ***** CGN 38 CLASS
C
   60 CONTINUE
      IF (SHCLAS(I).NE.2)GO TO 70
      XCS(I)= 2550.8
      STYPE(I)=2
      SHIPTD(I,1)=4
      SHIPTD(I,2)=50
      DO 65 J=1,4
          SELDEF(SD+J-1,1)=1
          SELDEF(SD+J-1,3)=1
          SDTIME(SD+J-1)=0.0
   65 CONTINUE
      SELDEF(SD  ,2)=4
      SELDEF(SD+1,2)=4
      SELDEF(SD+2,2)=5
      SELDEF(SD+3,2)=6
      SELDEF(SD  ,4)=4
      SELDEF(SD+1,4)=4
      SELDEF(SD+2,4)=3
      SELDEF(SD+3,4)=999
      SD=SD+4
      SLRBAT(I,1)=5
      SLRBAT(I,2)=2
      SLRBAT(I,3)=FC
      FCON(FC  ,3)=AZ
      FCON(FC+1,3)=AZ
```

```
      FCON(FC+2,3)=MZ+1
      MAG(MZ)=30
      MAG(MZ+1)=30
      MZ=MZ+2
      DO 64 J=1,3
            FCON(FC+J-1,1)=1
            FCON(FC+J-1,2)=1
            ADTIME(FC+J-1)=0.0
 64   CONTINUE
      FIRERS=FIRERS+1
      FC=FC+3
C
      SHWEPS(I,1)=0
      SHWEPS(I,2)=3
      SHWEPS(I,3)=0
      SHWEPS(I,4)=2
      SHWEPS(I,5)=1
      SHWEPS(I,6)=1
C
      GO TO 50
C
C     *****  CG 26 CLASS
C
C
 70   CONTINUE
      IF (SHCLAS(I).NE.3)GO TO 80
      XCS(I)= 2155.4
      STYPE(I)=1
      SHIPTO(I,1)=3
      SHIPTO(I,2)=50
      DO 75 J=1,3
            SELDEF(SD+J-1,1)=1
            SELDEF(SD+J-1,3)=1
            SDTIME(SD+J-1)=0.0
 75   CONTINUE
      SELDEF(SD  ,2)=4
      SELDEF(SD+1,2)=5
      SELDEF(SD+2,2)=6
      SELDEF(SD  ,4)=4
      SELDEF(SD+1,4)=5
      SELDEF(SD+2,4)=999
      SD=SD+3
      SERBAT(I,1)=2
      SERBAT(I,2)=1
      SERBAT(I,3)=FC
      FCON(FC  ,3)=MZ
      FCON(FC+1,3)=MZ
      MAG(MZ)=30
```

```
      MZ=MZ+1                                                           AD 06730
      DO 74 J=1,2                                                       AD 06740
            FCON(FC+J-1,1)=1                                            AD 06750
            FCON(FC+J-1,2)=1                                            AD 06760
            ADTIME(FC+J-1)=0.0                                          AD 06770
   74 CONTINUE                                                          AD 06780
      FIRERS=FIRERS+1                                                   AD 06790
      FC=FC+2                                                           AD 06800
C                                                                       AD 06810
      SHWEPS(I,1)=2                                                     AD 06820
      SHWEPS(I,2)=0                                                     AD 06830
      SHWEPS(I,3)=0                                                     AD 06840
      SHWEPS(I,4)=1                                                     AD 06850
      SHWEPS(I,5)=1                                                     AD 06860
      SHWEPS(I,6)=1                                                     AD 06870
C                                                                       AD 06880
      GO TO 50                                                          AD 06890
C                                                                       AD 06900
C     ***** GO TO CLASS                                                 AD 06910
C                                                                       AD 06920
C                                                                       AD 06930
   80 CONTINUE                                                          AD 06940
      IF (SHCLAS(I).NE.4)GO TO 90                                       AD 06950
      XCS(I)= 2390.0                                                    AD 06960
      STYPE(I)=1                                                        AD 06970
      SHIPTO(I,1)=2                                                     AD 06980
      SHIPTO(I,2)=50                                                    AD 06990
      DO 85 J=1,2                                                       AD 07000
            SELDEF(SD+J-1,1)=1                                          AD 07010
            SELDEF(SD+J-1,3)=1                                          AD 07020
            SDTIME(SD+J-1)=0.0                                          AD 07030
   85 CONTINUE                                                          AD 07040
      SELDEF(SD  ,2)=5                                                  AD 07050
      SELDEF(SD+1,2)=6                                                  AD 07060
      SELDEF(SD  ,4)=3                                                  AD 07070
      SELDEF(SD+1,4)=999                                                AD 07080
      SD=SD+2                                                           AD 07090
      SERBAT(I,1)=4                                                     AD 07100
      SERBAT(I,2)=2                                                     AD 07110
      SERBAT(I,3)=FC                                                    AD [illegible]
      FCON(FC  ,3)=AZ                                                   AD [illegible]
      FCON(FC+1,3)=AZ                                                   AD [illegible]
      FCON(FC+2,3)=AZ+1                                                 AD [illegible]
      FCON(FC+3,3)=AZ+1                                                 AD [illegible]
      AAG(AZ)=40                                                        AD [illegible]
      AAG(AZ+1)=40                                                      AD [illegible]
      AZ=AZ+2                                                           AD [illegible]
      DO [illegible] J=1,[illegible]                                    AD [illegible]
```

```
            FCON(FC+J-1,1)=1
            FCON(FC+J-1,2)=1
            ADTIME(FC+J-1)=0.0
 64      CONTINUE
         FIRERS=FIRERS+1
         FC=FC+4
C
         SHWEPS(I,1)=4
         SHWEPS(I,2)=0
         SHWEPS(I,3)=0
         SHWEPS(I,4)=0
         SHWEPS(I,5)=1
         SHWEPS(I,6)=1
C
         GO TO 90
C
C
C        ***** DDG 2 CLASS
C
C
 90      CONTINUE
         IF (SHCLAS(I).NE.5)GO TO 100
         XCS(I)= 1436.4
         STYPE(I)=2
         SHIPTD(I,1)=2
         SHIPTD(I,2)=SD
         DO 95 J=1,2
            SELDEF(SD+J-1,1)=1
            SELDEF(SD+J-1,3)=1
            SDTIM (SD+J-1)=0.0
 95      CONTINUE
         SELDEF(SD  ,2)=4
         SELDEF(SD+1,2)=4
         SELDEF(SD  ,4)=4
         SELDEF(SD+1,4)=4
         SD=SD+2
         SLRBAT(I,1)=2
         SLRBAT(I,2)=1
         SLRBAT(I,3)=FC
         FCON(FC  ,3)=MZ
         FCON(FC+1,3)=MZ
         MAG(MZ)=40
         MZ=MZ+1
         DO 94 J=1,2
            FCON(FC+J-1,1)=1
            FCON(FC+J-1,2)=1
            ADTIME(FC+J-1)=0.0
 94      CONTINUE
```

```
      FIRERS=FIRERS+1
      FC=FC+2
C
      SHWEPS(I,1)=0
      SHWEPS(I,2)=2
      SHWEPS(I,3)=0
      SHWEPS(I,4)=2
      SHWEPS(I,5)=0
      SHWEPS(I,6)=0
C
      GO TO 50
C
C
C     *****DDG 37 CLASS
C
C
100   CONTINUE
      IF (SHCLAS(I).NE.6)GO TO 110
      XCS(I)= 1713.3
      STYPE(I)=1
      SHIPTD(I,1)=2
      SHIPTD(I,2)=50
      DO 96 J=1,2
            SELCEF(SD+J-1,1)=1
            SELDEF(SD+J-1,3)=1
            SDTIME(SD+J-1)=0.0
96    CONTINUE
      SELDEF(SD  ,2)=4
      SELDEF(SD+1,2)=5
      SELDEF(SD  ,4)=4
      SELDEF(SD+1,4)=3
      SD=SD+2
      SLRBAT(I,1)=2
      SLRBAT(I,2)=1
      SLRBAT(I,3)=FC
      FCON(FC  ,3)=MZ
      FCON(FC+1,3)=MZ
      MAG(MZ)=40
      MZ=MZ+1
      DO 97 J=1,2
            FCON(FC+J-1,1)=1
            FCON(FC+J-1,2)=1
            ADTIME(FC+J-1)=0.0
97    CONTINUE
       FIRERS=FIRERS+1
      FC=FC+2
C
      SHWEPS(I,1)=2
```

```
      SHWEPS(I,2)=0
      SHWEPS(I,3)=0
      SHWEPS(I,4)=1
      SHWEPS(I,5)=1
      SHWEPS(I,6)=0
C
      GO TO 50
C
C
C     ***** DD 963
C
C
  110 CONTINUE
      IF (SHCLAS(I).NE.7)GO TO 120
      XCS(I)= 2213.0
      STYPE(I)=0
      SHIPTD(I,1)=5
      SHIPTD(I,2)=SD
      DO 98 J=1,5
            SELDEF(SD+J-1,1)=1
            SELDEF(SD+J-1,3)=1
            SDTIME(SD+J-1)=0.0
   98 CONTINUE
      SELDEF(SD  ,2)=3
      SELDEF(SD+1,2)=4
      SELDEF(SD+2,2)=4
      SELDEF(SD+3,2)=5
      SELDEF(SD+4,2)=5
      SELDEF(SD  ,4)=4
      SELDEF(SD+1,4)=4
      SELDEF(SD+2,4)=4
      SELDEF(SD+3,4)=3
      SELDEF(SD+4,4)=999
      SD=SD+5
C
      SHWEPS(I,1)=0
      SHWEPS(I,2)=0
      SHWEPS(I,3)=1
      SHWEPS(I,4)=2
      SHWEPS(I,5)=1
      SHWEPS(I,6)=1
C
      GO TO 50
C
C
C     ***** FFG 7 CLASS
C
C
```

```
  120 CONTINUE
      IF (SHCLAS(I).NE.8)GO TO 130
      XLS(I)= 1334.2
      STYPL(I)=2
      SHIPTD(I,1)=3
      SHIPTD(I,2)=SD
      DO 99 J=1,3
            SELDEF(SD+J-1,1)=1
            SELDEF(SD+J-1,3)=1
            SDTIME(SD+J-1)=0.0
   99 CONTINUE
      SELDEF(SD  ,2)=4
      SELDEF(SD+1,2)=5
      SELDEF(SD+2,2)=6
      SELDEF(SD  ,4)=4
      SELDEF(SD+1,4)=3
      SELDEF(SD+2,4)=999
      SD=SD+3
      SLRBAT(I,1)=1
      SLRBAT(I,2)=1
      SLRBAT(I,3)=FC
      FCON(FC   ,3)=MZ
      MAG(MZ)=30
      MZ=MZ+1
            FCON(FC      ,1)=1
            FCON(FC      ,2)=1
            ADTIME(FC       )=0.0
      FIRERS=FIRERS+1
      FC=FC+1
C
      SHWEPS(I,1)=0
      SHWEPS(I,2)=1
      SHWEPS(I,3)=0
      SHWEPS(I,4)=1
      SHWEPS(I,5)=1
      SHWEPS(I,6)=1
C
      GO TO 50
C
C
C      ***** FFG 1052 CLASS
C
C
  130 CONTINUE
      IF (SHCLAS(I).NE.9)GO TO 140
      XLS(I)= 1.11.2
      STYPL(I)=0
      SHIPTD(I,1)=3
```

```
      SHIPID(I,2)=SD
      DO 87 J=1,3
          SELDEF(SD+J-1,1)=1
          SELDEF(SD+J-1,3)=1
          SDTIME(SD+J-1)=0.0
   87 CONTINUE
      SELDEF(SD  ,2)=3
      SELDEF(SD+1,2)=4
      SELDEF(SD+2,2)=6
      SELDEF(SD  ,4)=4
      SELDEF(SD+1,4)=4
      SELDEF(SD+2,4)=999
      SD=SD+3
C
      SHWEPS(I,1)=0
      SHWEPS(I,2)=0
      SHWEPS(I,3)=1
      SHWEPS(I,4)=1
      SHWEPS(I,5)=0
      SHWEPS(I,6)=1
C
      GO TO 50
  140 CONTINUE
C
C     **** TICONDEROGA CLASS
C
      IF (SHCLAS(I).NE.10)GO TO 600
      XCS(I)= 2755.0
      STYPE(I)=2
      SHIPID(I,1)=4
      SHIPID(I,2)=SD
      DO 604 J=1,4
          SELDEF(SD+J-1,1)=1
          SELDEF(SD+J-1,3)=1
          SDTIME(SD+J-1)=0.0
  604 CONTINUE
      SELDEF(SD  ,2)=4
      SELDEF(SD+1,2)=4
      SELDEF(SD+2,2)=5
      SELDEF(SD+3,2)=5
      SELDEF(SD  ,4)=4
      SELDEF(SD+1,4)=4
      SELDEF(SD+2,4)=3
      SELDEF(SD+3,4)=999
      SD=SD+4
      SERBAT(I,1)=13
      SERBAT(I,2)=2
      SERBAT(I,3)=RC
```

```
      FCON(FC   ,3)=MZ
      FCON(FC+1,3)=MZ
      FCON(FC+2,3)=MZ
      FCON(FC+3,3)=MZ
      FCON(FC+4,3)=MZ
      FCON(FC+5,3)=MZ
      FCON(FC+6,3)=MZ
      FCON(FC+7,3)=MZ
      FCON(FC+8,3)=MZ
      FCON(FC+9,3)=MZ+1
      FCON(FC+10,3)=MZ+1
      FCON(FC+11,3)=MZ+1
      FCON(FC+12,3)=MZ+1
      FCON(FC+13,3)=MZ+1
      FCON(FC+14,3)=MZ+1
      FCON(FC+15,3)=MZ+1
      FCON(FC+16,3)=MZ+1
      FCON(FC+17,3)=MZ+1
      MAG(MZ)=50
      MAG(MZ+1)=50
      MZ=MZ+2
      DO 605 J=1,18
          FCON(FC+J-1,1)=1
          FCON(FC+J-1,2)=1
          ADTIME(FC+J-1)=0.0
605   CONTINUE
      FC=FC+18
      FIRERS=FIRERS+1
      SHWEPS(I,1)=0
      SHWEPS(I,2)=18
      SHWEPS(I,3)=0
      SHWEPS(I,4)=2
      SHWEPS(I,5)=1
      SHWEPS(I,6)=1
      GO TO 50
600   CONTINUE
C
C     ****** BUILD SOVIET SHIPS
C
C     *****   KIROV I CLASS
C
      IF (SHCLAS(I).NE.11)GO TO 610
      XMS(I)= 33.0
      STYPE(I)=1
      SHIPTD(I,1)=7
      SHIPTD(I,2)=50
      DO 609 J=1,7
          SFEEFF(50+J-1,1)=1
```

```
            SELDEF(SD+J-1,3)=1
            SDTIME(SD+J-1)=0.0
605     CONTINUE
        SELDEF(SD  ,2)=3
        SELDEF(SD+1,2)=3
        SELDEF(SD+2,2)=4
        SELDEF(SD+3,2)=4
        SELDEF(SD+4,2)=5
        SELDEF(SD+5,2)=5
        SELDEF(SD+6,2)=6
        SELDEF(SD  ,4)=10
        SELDEF(SD+1,4)=10
        SELDEF(SD+2,4)=4
        SELDEF(SD+3,4)=4
        SELDEF(SD+4,4)=3
        SELDEF(SD+5,4)=3
        SELDEF(SD+6,4)=999
        SD=SD+7
        SLRBAT(I,1)=12
        SLRBAT(I,2)=1
        SLRBAT(I,3)=FC
        FCON(FC   ,3)=MZ
        FCON(FC+1 ,3)=MZ
        FCON(FC+2 ,3)=MZ
        FCON(FC+3 ,3)=MZ
        FCON(FC+4 ,3)=MZ
        FCON(FC+5 ,3)=MZ
        FCON(FC+6 ,3)=MZ
        FCON(FC+7 ,3)=MZ
        FCON(FC+8 ,3)=MZ
        FCON(FC+9 ,3)=MZ
        FCON(FC+10,3)=MZ
        FCON(FC+11,3)=MZ
        MAG(MZ)=96
        MZ=MZ+1
        DO 607 J=1,12
            FCON(FC+J-1,1)=1
            FCON(FC+J-1,2)=1
            ADTIME(FC+J-1)=0.0
607     CONTINUE
        FC=FC+12
        FIRERS=FIRERS+1
        SHWEPS(I,1)=12
        SHWEPS(I,2)= 0
        SHWEPS(I,3)= 2
        SHWEPS(I,4)= 2
        SHWEPS(I,5)= 2
        SHWEPS(I,6)= 1
```

```
      GO TO 50
  610 CONTINUE
C
C     ***** KIROV CLASS (MOD 1 PD SAM INSTALLED)
C
C
      IF (SHCLAS(I).NE.12)GO TO 620
      XCS(I)= 3309.0
      STYPE(I)=1
      SHIPTD(I,1)=10
      SHIPTD(I,2)=SD
      DO 611 J=1,10
            SELDEF(SD+J-1,1)=1
            SELDEF(SD+J-1,3)=1
            SDTIME(SD+J-1)=0.0
  611 CONTINUE
      SELDEF(SD   ,2)=3
      SELDEF(SD+1,2)=3
      SELDEF(SD+2,2)=3
      SELDEF(SD+3,2)=3
      SELDEF(SD+4,2)=3
      SELDEF(SD+5,2)=3
      SELDEF(SD+6,2)=4
      SELDEF(SD+7,2)=5
      SELDEF(SD+8,2)=5
      SELDEF(SD+9,2)=6
      SELDEF(SD   ,4)=4
      SELDEF(SD+1,4)=10
      SELDEF(SD+2,4)=10
      SELDEF(SD+3,4)=16
      SELDEF(SD+4,4)=16
      SELDEF(SD+5,4)=16
      SELDEF(SD+6,4)=16
      SELDEF(SD+7,4)=3
      SELDEF(SD+8,4)=3
      SELDEF(SD+9,4)=999
      SD=SD+10
      SLRBAT(I,1)=12
      SLRBAT(I,2)=1
      SLRBAT(I,3)=FC
      FCON(FC   ,3)=MZ
      FCON(FC+1,3)=MZ
      FCON(FC+2,3)=MZ
      FCON(FC+3,3)=MZ
      FCON(FC+4,3)=MZ
      FCON(FC+5,3)=MZ
      FCON(FC+6,3)=MZ
      FCON(FC+7,3)=MZ
```

```
      FCON(FC+8,5)=MZ
      FCON(FC+9,5)=MZ
      FCON(FC+10,5)=MZ
      FCON(FC+11,5)=MZ
      MAG(MZ)=50
      MZ=MZ+1
      DO 612 J=1,12
           FCON(FC+J-1,1)=1
           FCON(FC+J-1,2)=1
           ADTIME(FC+J-1)=0.0
612   CONTINUE
      FC=FC+12
      FIRERS=FIRERS+1
      SHWEPS(I,1)=12
      SHWEPS(I,2)=0
      SHWEPS(I,3)=0
      SHWEPS(I,4)=1
      SHWEPS(I,5)=2
      SHWEPS(I,6)=1
      GO TO 50
620   CONTINUE
C
C     ***** KIEV CLASS
C
C
      IF (SHCLAS(I).NE.13)GO TO 630
      ACS(I)= 4555.0
      STYPE(I)=2
      SHIPTO(I,1)=5
      SHIPTO(I,2)=50
      DO 621 J=1,5
           SELDEF(SD+J-1,1)=1
           SELDEF(SD+J-1,3)=1
           SDTIME(SD+J-1)=0.0
621   CONTINUE
      SELDEF(SD  ,2)=4
      SELDEF(SD+1,2)=4
      SELDEF(SD+2,2)=4
      SELDEF(SD+3,2)=5
      SELDEF(SD+4,2)=5
      SELDEF(SD+5,2)=6
      SELDEF(SD  ,4)=10
      SELDEF(SD+1,4)=4
      SELDEF(SD+2,4)=4
      SELDEF(SD+3,4)=3
      SELDEF(SD+4,4)=4
      SELDEF(SD+5,4)=999
      SD=SD+6
```

```
      SERBAT(I,1)=2
      SERBAT(I,2)=1
      SERBAT(I,3)=FC
      FCON(FC  ,5)=MZ
      FCON(FC+1,5)=MZ+1
      MAG(MZ)=36
      MAG(MZ+1)=36
      MZ=MZ+2
      DO 623 J=1,2
            FCON(FC+J-1,1)=1
            FCON(FC+J-1,2)=1
            ADTIME(FC+J-1)=0.0
623   CONTINUE
      FC=FC+2
      FIRERS=FIRERS+1
      SHWEPS(I,1)=0
      SHWEPS(I,2)=2
      SHWEPS(I,3)=1
      SHWEPS(I,4)=2
      SHWEPS(I,5)=2
      SHWEPS(I,6)-1
      GO TO 50
630   CONTINUE
C
C     ***** BLK COM 1
C
C
      IF (SHCLAS(I).NE.14)GO TO 635
      XCS(I)= 2335.0
      STYPE(I)=1
      SHIPTD(I,1)=5
      SHIPTD(I,2)-50
      DO 631 J=1,5
            SELDEF(SD+J-1,1)=1
            SELDEF(SD+J-1,3)=1
            SDTIME(SD+J-1)=0.0
631   CONTINUE
      SELDEF(SD  ,2)=3
      SELDEF(SD+1,2)=3
      SELDEF(SD+2,2)=4
      SELDEF(SD+3,2)=5
      SELDEF(SD+4,2)=6
      SELDEF(SD  ,4)=10
      SELDEF(SD+1,4)=10
      SELDEF(SD+2,4)=4
      SELDEF(SD+3,4)=3
      SELDEF(SD+4,4)=99
      SD=SD+5
```

```
      SERBAT(I,1)=0
      SERBAT(I,2)=1
      SERBAT(I,3)=FC
      FCON(FC  ,3)=MZ
      FCON(FC+1,3)=MZ
      FCON(FC+2,3)=MZ
      FCON(FC+3,3)=MZ
      FCON(FC+4,3)=MZ
      FCON(FC+5,3)=MZ
      MAG(MZ)=64
      MZ=MZ+1
      DO 632 J=1,6
            FCON(FC+J-1,1)=1
            FCON(FC+J-1,2)=1
            ADTIME(FC+J-1)=0.0
632   CONTINUE
      FC=FC+6
      FIRERS=FIRERS+1
      SHWEPS(I,1)=0
      SHWEPS(I,2)=0
      SHWEPS(I,3)=2
      SHWEPS(I,4)=1
      SHWEPS(I,5)=1
      SHWEPS(I,6)=1
      GO TO 50
635   CONTINUE
C
C     ***** SEVREMENNYY CLASS
C
C
      IF (SHCLAS(I).NE.15)GO TO 640
      RCS(I)= 2250.0
      STYPE(I)=2
      SHIPTD(I,1)=4
      SHIPTD(I,2)=50
      DO 636 J=1,4
            SELDEF(SD+J-1,1)=1
            SELDEF(SD+J-1,3)=1
            SDTIME(SD+J-1)=0.0
636   CONTINUE
      SELDEF(SL  ,2)=4
      SELDEF(SL+1,2)=4
      SELDEF(SL+2,2)=5
      SELDEF(SL+3,2)=5
      SELDEF(SL  ,4)=4
      SELDEF(SL+1,4)=4
      SELDEF(SL+2,4)=5
      SELDEF(SL+3,4)=999
```

```
      SD=SD+4
      SLRBAT(I,1)=3
      SLRBAT(I,2)=1
      SLRBAT(I,3)=FC
      FCON(FC   ,3)=MZ
      FCON(FC+1,3)=MZ
      FCON(FC+2,3)=MZ
      MAG(MZ)=44
      MZ=MZ+1
      DO 637 J=1,3
           FCON(FC+J-1,1)=1
           FCON(FC+J-1,2)=1
           ADTIME(FC+J-1)=0.0
637   CONTINUE
      FC=FC+3
      FIRERS=FIRERS+1
      SHWEPS(I,1)=0
      SHWEPS(I,2)=3
      SHWEPS(I,3)=0
      SHWEPS(I,4)=2
      SHWEPS(I,5)=1
      SHWEPS(I,6)=1
      GO TO 50
640   CONTINUE
C
C     ***** OCALGY CLASS
C
C
      IF (SHCLAS(I).NE.16)GO TO 645
      XCS(I)= 1900.0
      STYPE(I)=0
      SHIPTD(I,1)=8
      SHIPTD(I,2)=50
      DO 641 J=1,6
           SELDEF(SD+J-1,1)=1
           SELDEF(SD+J-1,3)=1
           SDTIME(SD+J-1)=0.0
641   CONTINUE
      SELDEF(SD   ,2)=3
      SELDEF(SD+1,2)=3
      SELDEF(SD+2,2)=4
      SELDEF(SD+3,2)=4
      SELDEF(SD+4,2)=5
      SELDEF(SD+5,2)=6
      SELDEF(SD   ,4)=10
      SELDEF(SD+1,4)=10
      SELDEF(SD+2,4)=4
      SELDEF(SD+3,4)=4
```

```
      SELDEF(SD+4,4)=3
      SELDEF(SD+5,4)=999
      SD=SD+6
      SHWEPS(I,1)=0
      SHWEPS(I,2)=0
      SHWEPS(I,3)=2
      SHWEPS(I,4)=2
      SHWEPS(I,5)=1
      SHWEPS(I,6)=1
      GO TO 50
  645 CONTINUE
C
C     ***** MOSKVA CLASS
C
C
      IF (SHCLAS(I).NE.17)GO TO 650
      XCS(I)= 3000.0
      STYPE(I)=2
      SHIPTD(I,1)=4
      SHIPTD(I,2)=SD
      DO 647 J=1,4
         SELDEF(SD+J-1,1)=I
         SELDEF(SD+J-1,3)=1
         SDTIME(SD+J-1)=0.0
  647 CONTINUE
      SELDEF(SD  ,2)=3
      SELDEF(SD+1,2)=3
      SELDEF(SD+2,2)=4
      SELDEF(SD+3,2)=6
      SELDEF(SD  ,4)=11
      SELDEF(SD+1,4)=11
      SELDEF(SD+2,4)=4
      SELDEF(SD+3,4)=999
      SD=SD+5
      SERBAT(I,1)=2
      SERBAT(I,2)=1
      SERBAT(I,3)=FC
      FCON(FC  ,3)=MZ
      FCON(FC+1,3)=MZ
      FCON(FC+2,3)=MZ
      MAG(MZ)=44
      MZ=MZ+1
      DO 649 J=1,3
         FCON(FC+J-1,1)=I
         FCON(FC+J-1,2)=1
         ADTIME(FC+J-1)=0.0
  649 CONTINUE
      FC=FC+3
```

```
      FIRERS=FIRERS+1                                                  AD 13450
      SHWEPS(I,1)=0                                                    AD 13460
      SHWEPS(I,2)=2                                                    AD 13470
      SHWEPS(I,3)=2                                                    AD 13480
      SHWEPS(I,4)=1                                                    AD 13490
      SHWEPS(I,5)=0                                                    AD 13500
      SHWEPS(I,6)=1                                                    AD 13510
      GO TO 50                                                         AD 13520
  650 CONTINUE                                                         AD 13530
C                                                                      AD 13540
C     ***** KARA CLASS                                                 AD 13550
C                                                                      AD 13560
C                                                                      AD 13570
      IF (SHCLAS(I).NE.18)GO TO 655                                    AD 13580
      XCS(I)= 2200.0                                                   AD 13590
      STYPE(I)=2                                                       AD 13600
      SHIPTO(I,1)=4                                                    AD 13610
      SHIPTO(I,2)=SD                                                   AD 13620
      DO 653 J=1,4                                                     AD 13630
           SELDEF(SD+J-1,1)=1                                          AD 13640
           SELDEF(SD+J-1,3)=1                                          AD 13650
           SDTIME(SD+J-1)=0.0                                          AD 13660
  653 CONTINUE                                                         AD 13670
      SELDEF(SD  ,2)=3                                                 AD 13680
      SELDEF(SD+1,2)=4                                                 AD 13690
      SELDEF(SD+2,2)=5                                                 AD 13700
      SELDEF(SD+3,2)=6                                                 AD 13710
      SELDEF(SD  ,4)=10                                                AD 13720
      SELDEF(SD+1,4)=4                                                 AD 13730
      SELDEF(SD+2,4)=5                                                 AD 13740
      SELDEF(SD+3,4)=99                                                AD 13750
      SD=SD+5                                                          AD 13760
      SERBAT(I,1)=2                                                    AD 13770
      SERBAT(I,2)=2                                                    AD 13780
      SERBAT(I,3)=FC                                                   AD 13790
      FCON(FC  ,3)=MZ                                                  AD 13800
      FCON(FC+1,3)=MZ+1                                                AD 13810
      MAG(MZ)=22                                                       AD 13820
      MAG(MZ+1)=22                                                     AD 13830
      MZ=MZ+2                                                          AD 13840
      DO 651 J=1,2                                                     AD 13850
           FCON(FC+J-1,1)=1                                            AD 13860
           FCON(FC+J-1,2)=1                                            AD 13870
           ADTIME(FC+J-1)=0.0                                          AD 13880
  651 CONTINUE                                                         AD 13890
      FC=FC+2                                                          AD 13900
      FIRERS=FIRERS+1                                                  AD 13910
      SHWEPS(I,1)=0                                                    AD 13920
```

```
      SHWEPS(I,2)=1
      SHWEPS(I,3)=1
      SHWEPS(I,4)=1
      SHWEPS(I,5)=1
      SHWEPS(I,6)=1
      GO TO 50
  655 CONTINUE
C
C     ***** KRESTA II CLASS
C
C
      IF (SHCLAS(I).NE.19)GO TO 660
      XCS(I)= 2000.0
      STYPE(I)=2
      SHIPID(I,1)=3
      SHIPID(I,2)=SD
      DO 656 J=1,3
           SELDEF(SD+J-1,1)=1
           SELDEF(SD+J-1,3)=1
           SDTIME(SD+J-1)=0.0
  656 CONTINUE
      SELDEF(SD  ,2)=4
      SELDEF(SD+1,2)=5
      SELDEF(SD+2,2)=6
      SELDEF(SD  ,4)=4
      SELDEF(SD+1,4)=3
      SELDEF(SD+2,4)=999
      SD=SD+3
      SLRBAT(I,1)=2
      SLRBAT(I,2)=2
      SLRBAT(I,3)=FC
      FCON(FC  ,3)=MZ
      FCON(FC+1,3)=MZ+1
      MAG(MZ)=22
      MAG(MZ+1)=22
      MZ=MZ+2
      DO 657 J=1,2
           FCON(FC+J-1,1)=1
           FCON(FC+J-1,2)=1
           ADTIME(FC+J-1)=0.0
  657 CONTINUE
      FC=FC+2
      FIRERS=FIRERS+1
      SHWEPS(I,1)=0
      SHWEPS(I,2)=2
      SHWEPS(I,3)=0
      SHWEPS(I,4)=1
      SHWEPS(I,5)=1
```

```
      SHWEPS(I,6)=1
      GO TO 50
 660  CONTINUE
C
C     ***** KYNDA CLASS
C
C
      IF (SHCLAS(I).NE.20)GO TO 665
      XCS(I)= 1350.0
      STYPE(I)=2
      SHIPTD(I,1)=2
      SHIPTD(I,2)=SD
      DO 664 J=1,2
           SELDEF(SD+J-1,1)=1
           SELDEF(SD+J-1,3)=1
           SDTIME(SD+J-1)=0.0
 664  CONTINUE
      SELDEF(SD  ,2)=4
      SELDEF(SD+1,2)=4
      SELDEF(SD  ,4)=4
      SELDEF(SD+1,4)=4
      SD=SD+2
      SLRBAT(I,1)=1
      SLRBAT(I,2)=1
      SLRBAT(I,3)=FC
      FCON(FC  ,3)=MZ
      MAG(MZ)=22
      MAG(MZ+1)=30
      MZ=MZ+2
      DO 662 J=1,3
           FCON(FC+J-1,1)=1
           FCON(FC+J-1,2)=1
           ADTIME(FC+J-1)=0.0
 662  CONTINUE
      FC=FC+1
      FIRERS=FIRERS+1
      SHWEPS(I,1)=0
      SHWEPS(I,2)=1
      SHWEPS(I,3)=0
      SHWEPS(I,4)=2
      SHWEPS(I,5)=0
      SHWEPS(I,6)=0
      GO TO 50
 665  CONTINUE
C
C     ***** MOD KASHIN CLASS
C
C
```

```
      IF (SHCLAS(I).NE.21)GO TO 670
      XCS(I)= 1300.0
      STYPE(I)=2
      SHIPTD(I,1)=4
      SHIPTD(I,2)=SD
      DO 666 J=1,4
            SELDEF(SD+J-1,1)=1
            SELDEF(SD+J-1,3)=1
            SDTIME(SD+J-1)=0.0
  666 CONTINUE
      SELDEF(SD  ,2)=4
      SELDEF(SD+1,2)=4
      SELDEF(SD+2,2)=5
      SELDEF(SD+3,2)=6
      SELDEF(SD  ,4)=4
      SELDEF(SD+1,4)=4
      SELDEF(SD+2,4)=3
      SELDEF(SD+3,4)=10
      SD=SD+4
      SLRBAT(I,1)=2
      SLRBAT(I,2)=2
      SLRBAT(I,3)=FC
      FCON(FC  ,3)=MZ
      FCON(FC+1,3)=MZ+1
      MAG(MZ)=22
      MAG(MZ+1)=22
      MZ=MZ+2
      DO 667 J=1,2
            FCON(FC+J-1,1)=1
            FCON(FC+J-1,2)=1
            ADTIME(FC+J-1)=0.0
  667 CONTINUE
      FC=FC+2
      FIRERS=FIRERS+1
      SHWEPS(I,1)= 0
      SHWEPS(I,2)= 2
      SHWEPS(I,3)= 0
      SHWEPS(I,4)= 2
      SHWEPS(I,5)= 1
      SHWEPS(I,6)= 1
      GO TO 50
  670 CONTINUE
C
C     ***** KRIVAK CLASS
C
C
      IF (SHCLAS(I).NE.22)GO TO 675
      XCS(I)= 1100.0
```

```
      STYPE(I)=0
      SHIPTD(I,1)=4
      SHIPTD(I,2)=SD
      DO 676 J=1,4
         SELDEF(SD+J-1,1)=1
         SELDEF(SD+J-1,3)=1
         SDTIME(SD+J-1)=0.0
  676 CONTINUE
      SELDEF(SD  ,2)=3
      SELDEF(SD+1,2)=3
      SELDEF(SD+2,2)=4
      SELDEF(SD+3,2)=4
      SELDEF(SD  ,4)=10
      SELDEF(SD+1,4)=10
      SELDEF(SD+2,4)=4
      SELDEF(SD+3,4)=4
      SD=SD+4
      SHWEPS(I,1)= 0
      SHWEPS(I,2)= 0
      SHWEPS(I,3)= 2
      SHWEPS(I,4)= 2
      SHWEPS(I,5)= 0
      SHWEPS(I,6)= 0
      GO TO 50
  675 CONTINUE
C
C     ***** LARGE AUXILIARY WITH PD SA4 SYSTEM
C
C
      IF (SHCLAS(I).NE.23)GO TO 600
      XCS(I)= 3000.0
      STYPE(I)=0
      SHIPTD(I,1)=1
      SHIPTD(I,2)=SD
      DO 677 J=1,1
         SELDEF(SD+J-1,1)=1
         SELDEF(SD+J-1,3)=1
         SDTIME(SD+J-1)=0.0
  677 CONTINUE
      SELDEF(SD  ,2)=3
      SELDEF(SD  ,4)=4
      SD=SD+1
      SHWEPS(I,1)= 0
      SHWEPS(I,2)= 0
      SHWEPS(I,3)= 1
      SHWEPS(I,4)= 0
      SHWEPS(I,5)= 0
      SHWEPS(I,6)= 0
```

```
      GO TO 50
  685 CONTINUE
C
C     *****  CALIFORNIA CLASS
C
C
      IF (SHCLAS(I).NE.24)GO TO 685
      XCS(I)= 2000.0
      STYPE(I)=2
      SHIPTD(I,1)=4
      SHIPTD(I,2)=SD
      DO 686  J=1,4
            SELDEF(SD+J-1,1)=1
            SELDEF(SD+J-1,3)=1
            SDTIME(SD+J-1)=0.0
  686 CONTINUE
      SELDEF(SD   ,2)=4
      SELDEF(SD+1,2)=4
      SELDEF(SD+2,2)=5
      SELDEF(SD+3,2)=6
      SELDEF(SD   ,4)=4
      SELDEF(SD+1,4)=4
      SELDEF(SD+2,4)=3
      SELDEF(SD+3,4)=999
      SD=SD+4
      SLRBAT(I,1)=4
      SLRBAT(I,2)=2
      SLRBAT(I,3)=FC
      FCON(FC   ,3)=MZ
      FCON(FC+1,3)=MZ
      FCON(FC+2,3)=MZ+1
      FCON(FC+3,3)=MZ+1
      MAG(MZ)=40
      MAG(MZ+1)=40
      MZ=MZ+2
      DO 687  J=1,4
            FCON(FC+J-1,1)=1
            FCON(FC+J-1,2)=1
            ADTIME(FC+J-1)=0.0
  687 CONTINUE
      FC=FC+4
      ARRES=ARRES+1
      SHWEPS(I,1)=0
      SHWEPS(I,2)=4
      SHWEPS(I,3)=0
      SHWEPS(I,4)=2
      SHWEPS(I,5)=1
      SHWEPS(I,6)=1
```

```
      GO TO 50
265   CONTINUE
C  CCCCCCCCCCCCNEXT INSERT POINT ABOVE       *********************
      XCS(I) = DXCS
      STYPE(I) = 3
C
      SHWEPS(I,1)=0
      SHWEPS(I,2)=0
      SHWEPS(I,3)=0
      SHWEPS(I,4)=0
      SHWEPS(I,5)=0
      SHWEPS(I,6)=0
C
 50   CONTINUE
C
C
C     INITIAL ACTUAL NR OF AD BATTERIES, SD BATTERIES, MAGAZINES
C
      NBAT=FC-1
      MAGTOT=MZ-1
      SDTOT=SC-1
      ONE(1)=0
      ONE(2)=0
      TWO(1)=0
      TWO(2)=0
      MAGCAP=0
      IF(MAGTOT.LT.1)GO TO 153
      DO 149 I=1,MAGTOT
          MAGCP(I)=1
          MAGCAP=MAGCAP+MAG(I)
149   CONTINUE
      DO 155 I=1,NBAT
          MAGASN(FIRCON(I,3))=FIRCON(I,1)
155   CONTINUE
153   CONTINUE
C
C     TARGET INCOMING MISSILES IAW TARGET RADAR CROSS SECTION
C
      RCS(1)=XCS(1)
      IF(NSHIPS.GT.1)GO TO 151
      RCS(1)=1.0
      GO TO 152
151   CONTINUE
      DO 150 I=2,NSHIPS
          RCS(I)=XCS(I)+RCS(I-1)
150   CONTINUE
152   CONTINUE
C
```

```
      DO 160 I=1,NSHIPS
         RCS(I)=RCS(I)/RCS(NSHIPS)
         HITS(I)=0
         TARG(I)=0
  160 CONTINUE
C
      DO 165 I=1,ATTACK
         CMRES(I,1)=0
          DO 168 J=1,NSHIPS
             IF(RAND(RAN).GT.RCS(J))GO TO 168
             MTARG(I)=J
             CMRES(I,2)=J
             GO TO 170
  168     CONTINUE
  170     RAN=RAN+1
          IF (RAN.GT.990)CALL ROLL(RAN,RAND,IX1)
  165 CONTINUE
C
C     IF HVU TARGETING POSSIBLE, AUGMENT TARGETING
C
      IF(AUG.EQ.0)GO TO 171
        DO 172 I=1,ATTACK
             RAN=RAN+1
             IF (RAN.GT.990)CALL ROLL(RAN,RAND,IX1)
             IF (RAND(RAN).GT.HVTPER)GO TO 172
             RAN=RAN+1
             IF (RAN.GT.990)CALL ROLL(RAN,RAND,IX1)
             MTARG(I)=MTARG(I)-IFIX(HVTVUL*NSHIPS*RAND(RAN))
             IF(MTARG(I).LT.1)MTARG(I)=1
             RAN=RAN+1
             IF (RAN.GT.990)CALL ROLL(RAN,RAND,IX1)
  172   CONTINUE
  171 CONTINUE
      DO 173 I=1,ATTACK
         TARG(MTARG(I))=TARG(MTARG(I))+1
  173 CONTINUE
C
C     CALCULATION OF FIRE ENVELOPE THRESHOLDS
C
      ENVEL(1,1)=RANGE(1,1)+((RANGE(1,1)/SAMVEL)*CMVEL)
      ENVEL(2,1)=RANGE(2,1)+((RANGE(2,1)/SAMVEL)*CMVEL)
      ENVEL(1,3)=RANGE(1,2)+((RANGE(1,2)/SAMVEL)*CMVEL)
      ENVEL(2,3)=RANGE(2,2)+((RANGE(2,2)/SAMVEL)*CMVEL)
      Y=RADAR-(CMVEL*TRACK)
      IF(ENVEL(1,3).GT.Y)ENVEL(1,3)=Y
      IF(ENVEL(2,3).GT.Y)ENVEL(2,3)=Y
C     *****NOTE CORRECTIVE MEASURE TAKEN ELIMINATES (ASSES*SAMVEL)
      ENVEL(1,2)=ENVEL(1,1)+(CMVEL*(ASSES          ))+
```

```
     &       (((ENVEL(1,1)+(CMVOL*ASSES))/SAMVOL)*CMVOL)
      ENVEL(2,2)=ENVEL(2,1)+(CMVOL*(ASSES          ))+
     &       (((ENVEL(2,1)+(CMVOL*ASSES))/SAMVOL)*CMVOL)
      DO 177 I=1,20
         FIRENV(I,1)=0.0
         FIRENV(I,2)=0.0
         SHENV(I,1)=0.0
         SHENV(I,2)=0.0
         SHENV(I,3)=0.0
  177 CONTINUE
      DO 180 I=1,NSHIPS
        IF((STYPE(I).NE.0).AND.(STYPE(I).NE.3))GO TO 185
            FIRENV(I,1)=FLOAT(I)
        GO TO 180
  185   CONTINUE
C
        FIRENV(I,1)=FLOAT(I)
        FIRENV(I,2)=ENVEL(STYPE(I),3)+SPOS(I)
        SHENV(I,1)=ENVEL(STYPE(I),1)+SPOS(I)
        SHENV(I,2)=ENVEL(STYPE(I),2)+SPOS(I)
        SHENV(I,3)=ENVEL(STYPE(I),3)+SPOS(I)
  180 CONTINUE
C     WRITE(5,181)SHENV(1,1),SHENV(1,2),SHENV(1,3)
C 181 FORMAT(1X,3(3X,F7.2))
C
C     SORT ENVELOPES IN GEOGRAPHIC ORDER HIGHEST TO LOWEST
C
      IF(NSHIPS.EQ.1) GO TO 187
      NS=NSHIPS-1
      FLAG=1
  190 CONTINUE
      IF(FLAG.EQ.0)GO TO 193
         FLAG=0
        DO 195 I=1,NS
          IF(FIRENV(I,2).GE.FIRENV(I+1,2))GO TO 195
              DO 199 K=1,2
                  X(K)=FIRENV(I,K)
                  FIRENV(I,K)=FIRENV(I+1,K)
                  FIRENV(I+1,K)=X(K)
  199         CONTINUE
          FLAG=1
  195   CONTINUE
        GO TO 190
  193 CONTINUE
C
  187 CONTINUE
C
C     SORT FIRECON IN ORDER FROM MAX TO MIN RANGE
```

```
C
      IF(NBAT.LT.1)GO  TO 302
      N=1
      DO 300 I=1,NSHIPS
          P=IFIX(FIRENV(I,1))
          DO 305 J=1,NBAT
              IF (FCON(J,1).NE.P)GO TO 305
                  FIRCON(N,1)=P
                      FIRCON(N,2)=9,9999
                      FIRCON(N,3)=FCON(J,3)
                      N=N+1
  305     CONTINUE
  300 CONTINUE
  302 CONTINUE
C
C
C     ESTABLISH ASCM INITIAL PARAMETERS
C
      MAXENV=FIRENV(1,2)
      DO 303 I=1,NSHIPS
          IF(SPOS(I).GT.MAXENV)MAXENV=SPOS(I)
  303 CONTINUE
C
      DO 310 I=1,ATTACK
          YY=FLOAT(I)
          CMDATA(I,1)=MAXENV+(YY*TIMINT*CMVOL)
          CMDATA(I,2)=CMDATA(I,1)
          CMDATA(I,3)=(CMDATA(I,1)-SPOS(MTARG(I)))/CMVOL
          CMRES(I,1)=0
          CMRES(I,2)=0
  310 CONTINUE
C
C     IF ATTACK IS IN 2 WAVES, MOVE 2ND HALF OF MISSILES BACK WAVSEP
C
      IF(WAVE.EQ.1)GO TO 309
      IF(ATTACK.LT.2)GO TO 309
      II = ATTACK/2
      DO 308 I=II,ATTACK
          CMDATA(I,1)=CMDATA(I,1)+(WAVSEP*CMVOL)
          CMDATA(I,2)=CMDATA(I,1)
          CMDATA(I,3)=CMDATA(I,3)+WAVSEP
  308 CONTINUE
  309 CONTINUE
C
C
      DO 307 I=1,[illegible]
          FIRCO(I)=0
  307 CONTINUE
```

```
C
C
C
C     ******************************************************************
C
C              COMMENCE ENGAGEMENT
C
C     ******************************************************************
C
C
C
C     MOVE MISSILE TO THE FIRST AD SAM MISSILE THRESHOLD
C
      Z=1
C
C     LOOP ON MISSILES 777 LOOP
C
      DO 777 M=1,ATTACK
C
C        IF NO AREA DEFENSE SHIPS, GO DIRECTLY TO ENDGAME
            IF(FIRERS.LT.1)GO TO 700
C
C        IF PEN OPTION INVOKED, GO DIRECTLY TO ENDGAME
         RAN=RAN+1
         IF(RAN.GT.990)CALL ROLL(RAN,RAND,IXT)
         IF((PEN.EQ.1).AND.(RAND(RAN).LT.PENPLR))GO TO 700
C
C        IF DELAY INVOKED, MOVE THE MISSILES IN THE DELAY TIME
            IF(DELAY.EQ.1)CMDATA(M,2)=CMDATA(M,1)-(DT*CMVUL)
C
C        IF C-CUBE DEGREDATION EVOKED, CHECK FOR MISSILE
C           APPLICABILITY AND MOVE MISSILE
            IF(  (CCCUBE.NE.1).OR.(RAND(RAN).GT.C3DEGP))GO TO 313
               RAN=RAN+1
               CMDATA(M,2)=CMDATA(M,2)-(CMVUL*RAND(RAN)*C3DTIM)
               IF(RAN.GT.990)CALL ROLL(RAN,RAND,IXT)
  313       CONTINUE
C
C           CHECK TO SEE IF MISSILE IS NOW WITHIN A FIRING ENVELOPE
C                 IF YES, GO TO MISSILE IMPACT CHECKS
            IF(CMDATA(M,2).LT.FIRENV(1,2))GO TO 312
C
C           MOVE THE MISSILES TO THE FIRST THRESHOLD
                  CMDATA(M,2)=FIRENV(1,2)-.01
  312             CONTINUE
                  CMPOS=CMDATA(M,2)
                  T= (CMDATA(M,1)-CMDATA(M,2))/CMVEL
C
```

```
C
C         CHECK FOR MISSILE IMPACT
C
  311     CONTINUE
C
          IF(T.GE.CMDATA(M,3)) GO TO 760
C
C
C         SELECT FIRING BATTERY WHEN MISSILE ARRIVES AT NEXT THRESHOLD
C
          FLAG=0
          DO 350  I=1,NBAT
              IF(SHENV(FIRCON(I,1),3).LT.CMDATA(M,2))GO TO 350
              IF(ADTIME(I).GT.T)GO TO 350
              IF(T.GT.FLOAT(FIRCON(I,2)))GO TO 350
              IF (SHENV(FIRCON(I,1),1).GT.CMDATA(M,2))GO TO 350
              IF(MAG(FIRCON(I,3)).LT.1)GO TO 350
              IF(FLOAT(FIRCON(I,2)).LT.ADTIME(I))GO TO 350
              FLAG=1
              BATRY=I
              GO TO 360
  350     CONTINUE
  360     CONTINUE
C
C         IF NO BATTERY SELECTED, SEQUENCE TO NEXT THRESHOLD
          IF(FLAG.EQ.0) GO TO 440
C
C         CHECK MAGAZINE STATUS AND SELECT FIRING DOCTRINE
C
  400     CONTINUE
          RAN = RAN+1
          MAGNR=FIRCON(BATRY,3)
          Z=Z+1
C         IF(MAG(MAGNR).LT.1) GO TO 440
C         IF(FIRCON(BATRY,2).LT.T)GO TO 440
C ************BELOW QUESTION
          IF(CMDATA(M,2).LT.SHENV(FIRCON(BATRY,1),1))GO TO 440
          N=STYPE(FIRCON(BATRY,1))
          IF(MAG(MAGNR).LT.2)GO TO 370
          IF(CMDATA(M,2).GT.SHENV(FIRCON(BATRY,1),2))GO TO 370
          FIRE=2
          TWO(N)=TWO(N)+1
          MAG(MAGNR)=MAG(MAGNR)-2
          GO TO 380
  370     FIRE = 1
          ONE(N)=ONE(N)+1
          MAG(MAGNR)=MAG(MAGNR)-1
  380     CONTINUE
          IF(MAG(MAGNR).LT.1)MAGUP(MAGNR)=...
```

```
      FIRED(N)=FIRED(N)+FIRE
C
C     CALCULATE INTERCEPT TIME, CHECK FOR PRIOR MISSILE IMPACT
C        OR BATTERY DESTRUCTION PRIOR TO INTERCEPT
C
      TINTER=T+((CMDATA(M,2)-SPOS(FIRCON(BATRY,1)))/(SAMVEL+CMVEL))
      IF(CMDATA(M,3).GT.TINTER) GO TO 403
      IF(FLOAT(FIRCON(BATRY,2)).GT.TINTER)GO TO 403
  410 ADTIME(BATRY)=CMDATA(M,3)+CYCLE(N)+ASSES
      GO TO 750
C
C
C
C
  403 MR=(FLOAT(FIRCON(BATRY,2)))
      IF(TINTER.LT.MR)GO TO 400
      CMPOS=CMDATA(M,1)-(CMVEL*(MR+ASSES))
      CMDATA(M,2)=CMPOS
      TINTER=MR+ASSES
      T=TINTER
      ADTIME(BATRY)=TINTER+ASSES+CYCLE(N)
      GO TO 440
  400 CONTINUE
      ADTIME(BATRY)=TINTER+ASSES
      IF(FIRE.EQ.2)ADTIME(BATRY)=TINTER+ASSES+SALVO
      FLAG=0
       YY = PK(N,CMCLAS)
       P=(AXIS(MTARG(M))-AXIS(FIRCON(BATRY,1)))
       IF((P.EQ.1).OR.(P.EQ.-1)) YY=PK(N,CMCLAS)-DAGEG
C      IF(((P.EQ.1).OR.(P.EQ.-1)).AND.((CMDATA(M,1)-SPOS(FIRCON(BATRY,
C    &       1)-(CMVEL*1)).LT.10.0)) YY=PK(N,CMCLAS)-
C    &       (DAGEG*(1.0-(CMDATA(M,2)-SPOS(FIRCON(BATRY,1)))/1).0))
       IF(((P.EQ.2).OR.(P.EQ.-2))) YY=PK(N,CMCLAS)-(2.0*DAGEG)
C
      IF(FIRE.EQ.2)GO TO 405
      IF(RAND(RAN).LT.YY)FLAG=1
      GO TO 415
  405 CONTINUE
C
      Y=1.0-((1.0-YY)*(1.0-YY))
      IF(RAND(RAN).LT.Y)FLAG=1
  415 CONTINUE
C
C     IF FLAG=1 THE INCOMING ASCM WAS SHOT DOWN
C
      FAN=FAN+1
      IF(FAN.GT.9990)CALL RULE(RA., , IXI)
C     ****************TEST PRINT
```

```
C           WRITE(6,381)FIRE,CMDATA(M,2),FLAG
C381         FORMAT(1X,I2,3X,F7.2,3X,I2)
            IF(FLAG.EQ.0) GO TO 420
            CARES(M,1)=N
            CARES(M,2)=FIRCON(BATRY,1)
            ADTIME(BATRY)=TINTER+ASSES+CYCLE(N)
            GO TO 777
C
C           NOW HANDLE THE INCOMING MISSILES WHICH SURVIVED THE DEFENDER
C            CAN THE BATTERY RE-ENGAGE?
C
 420        CONTINUE
            CMDATA(M,2)=CMDATA(M,1)-(CMVOL*(TINTER+ASSES))
            T = TINTER+ASSES +.01
            IF(T.GT.CMDATA(M,3))GO TO 410
            IF(CMDATA(M,2) .LT.SHENV(FIRCON(BATRY,1),1))GO TO 430
            IF(MAG(MAGNR).LT.1) GO TO 430
            IF(FLOAT(FIRCON(BATRY,2)).LT.T)GO TO 430
            ADTIME(BATRY)=T
            GO TO 440
C
C           NOW COVER THE CASE WHERE RE-ENGAGEMENT BY THE SAME BATTERY
C                IS NOT POSSIBLE
C
 430        CONTINUE
            ADTIME(BATRY)=T+CYCLE(N)
 440        CONTINUE
C
C           DETERMINE TIME TO NEXT THRESHOLD
C
            CMPOS=CMDATA(M,2)
            FLAG=0
            DO 500 I=1,NSHIPS
                 IF(FIRENV(I,2).GT.CMPOS)GO TO 500
                 TNT=(CMDATA(M,1)-FIRENV(I,2))/CMVOL
                 FLAG=1
                 GO TO 510
 500        CONTINUE
 510        CONTINUE
            IF(FLAG.EQ.0)TNT=CMDATA(M,3)
C
C           CHECK FOR A BATTERY BEING FREED PRIOR TO THE THRESHOLD
C
            FLAG=0
            DO 520 I=1,NEXT
               IF((ACTIME(I).LT.T).OR.(ACTIME(I).GT.TNT))GO TO 520
               IF(T.GT.FLOAT(FIRCON(I,2)))GO TO 520
               IF(SHENV(FIRCON(I,1),3).LT.CMPOS)GO TO 520
```

```
      IF(SHENV(FIRCON(I,1),1).GT.CMPOS)GO TO 520
      IF(FLOAT(FIRCON(I,2)).LT.ADTIME(I))GO TO 520
      IF(MAG(FIRCON(I,3)).LT.1)GO TO 520
      BATRY=I
      T=ADTIME(I)
C        ADVANCE TIME FOR C-CUBE DEGRADATION IF APPLICABLE
      IF((CCCDEG.NE.1).OR.(RAND(RAN).GT.C3DEGP))GO TO 505
        RAN=RAN+1
        T=T+(RAND(RAN)*C3DTIM)
        IF(RAN.GT.990)CALL ROLL(RAN,RAND,IXT)
 505  CONTINUE
      CMDATA(M,2)=CMDATA(M,1)-(CMVEL*T)
      CMPOS=CMDATA(M,2)
      GO TO 400
 520  CONTINUE
 530  CONTINUE
      T=TNI
      IF((CCCDEG.NE.1).OR.(RAND(RAN).GT.C3DEGP))GO TO 535
        RAN=RAN+1
        T=T+(RAND(RAN)*C3DTIM)
        IF(RAN.GT.990)CALL ROLL(RAN,RAND,IXT)
 535  CONTINUE
      CMDATA(M,2)=CMDATA(M,1)-((CMVEL*T)+.01)
      CMPOS=CMDATA(M,2)
      GO TO 311
C
C
C ******COMMENCE ENDGAME - RESOLUTION OF POINT DEFENSE SYSTEMS
 700  CONTINUE
      TARGET=MTARG(M)
      IF(STYPE(TARGET).NE.3)GO TO 703
        HITS(P)=HITS(P)+1
        GO TO 777
 703  CONTINUE
      FILE=SHIPID(TARGET,2)
      NS=SHIPID(TARGET,1)
      U=FILE+NS-1
      NS=0
      DO 705 I=FILE,U
        IF(CMDATA(M,3).LT.SDTIME(I))GO TO 705
        IF(SELDEF(I,3).EQ.0)GO TO 705
        IF(SELDEF(I,4).LT.1)GO TO 705
        IF(NS.EQ.SELDEF(I,2))GO TO 705
        SELDEF(I,4)=SELDEF(I,4)-1
        FIRED(SELDEF(I,2))=FIRED(SELDEF(I,2))+1
        SDTIME(I)=CMDATA(M,3)+CYCLE(SELDEF(I,2))
        RAN=RAN+1
        IF(RAN.GT.990)CALL ROLL(RAN,RAND,IXT)
```

```
      IF(RAND(KAN).GT.PR(SELDEF(I,2),CMCLAS))GO TO 764
      KAN=KAN+1
      IF(KAN.GT.990)CALL ROLL(KAN,RAND,IXT)
      CMRES(M,1)=SELDEF(I,2)
      CMRES(M,2)=TARGET
      GO TO 777
764   CONTINUE
      KAN=KAN+1
      IF(KAN.GT.990)CALL ROLL(KAN,RAND,IXT)
765   CONTINUE
      NS=SELDEF(I,2)
763   CONTINUE
C
C *****  COMMENCE DAMAGE ASSESSMENT PORTION OF PROGRAM
C
      P=MTARG(M)
      HITS(P)=HITS(P)+1
      IF(SHCLAS(P).EQ.1)GO TO 855
      IF((SHCLAS(P).NE.1).AND.(HITS(P).GT.3))GO TO 777
      IF((STYPE(P).EQ.0).AND.(HITS(P).GT.2))GO TO 857
      IF(STYPE(P).EQ.0)GO TO 852
      FC=SERBAT(P,3)
      NS=SERBAT(P,1)
      NR=SERBAT(P,2)
      NS=FIRCON(FC,3)
      II=IFIX(GMDATA(4,5))
      Y=RAND(KAN)
      KAN=KAN+1
      IF(KAN.GT.990)CALL ROLL(KAN,RAND,IXT)
      IF(Y.LT.0.15) GO TO 851
      IF(HITS(P).GT.2)GO TO 851
      IF(Y.LT.0.2) GO TO 852
      IF(Y.GT.0.30) GO TO 820
      MAGZP(MP)=0
      DO 819 I=1,NLAT
       IF((FIRCON(I,3).EQ.NS).AND.(II.EQ.FIRCON(I,2)))FIRCON(I,2)=II
819   CONTINUE
      GO TO 852
820   CONTINUE
      IF(MR.EQ.1)GO TO 852
      MR=MR+1
      MAGZP(MR)=0
      DO 821 I=1,NLAT
       IF((FIRCON(I,3).EQ.NR).AND.(II.EQ.FIRCON(I,2)))FIRCON(I,2)=II
821   CONTINUE
      GO TO 852
851   CONTINUE
      DO 854 I=1,NLAT
```

```
      IF((FIRCON(I,1).EQ.P).AND.(FIRCON(I,2).GT.II))FIRCON(I,2)=II
854   CONTINUE
857   CONTINUE
      YY=1.0
      GO TO 856
852   CONTINUE
      YY=.33
      GO TO 856
855   CONTINUE
      YY=.2
856   CONTINUE
      NS=SHIPTE(P,1)
      DO 860 I=1,NS
         Y=RAND(RAN)
         RAN=RAN+1
         IF (RAN.GT.990) CALL RELL(RAY,RAND,IXT)
         IF(Y.LT.YY) SELDEF(SHIPTD(P,2)+I-1,3)=0
         IF(SECLAS(P).EQ.1)GO TO 860
         IF(HITS(P).GE.3)SELDEF(SHIPTD(P,2)+I-1,3)=0
860   CONTINUE
C
C     END OF LOOP ON MISSILES LABEL 777
C
777   CONTINUE
C
C     DATA PRESERVATION
C
C
      DO 861 I=1,NMAT
         IF(HITS(FIRCON(I,1)).GE.3)MAGOP(FIRCON(I,3))=0
861   CONTINUE
C
C
C
      IF(MAGTOT.LT.1)GO TO 853
      DO 865 I=1,MAGTOT
        IF(MAGOP(I).EQ.1)MAGKT=MAGKT+MAG(I)
        IF(MAGOP(I).EQ.1)KNOKE4(MAGAS1(I))=KNOKE4(MAGAS1(I))+MAG(I)
        IF(MAGOP(I).EQ.0)MAGOST=MAGOST+MAG(I)
865   CONTINUE
853   CONTINUE
C
      ONET(1)=ONET(1)+FLOAT(ONE(1))
      TWOT(1)=TWOT(1)+FLOAT(TWO(1))
      ONET(2)=ONET(2)+FLOAT(ONE(2))
      TWOT(2)=TWOT(2)+FLOAT(TWO(2))
C
      DO 870 I=1,NSHIPS
```

```
      HITLT=HITLT+HITS(I)
      HTOTAL(I)=HTOTAL(I)+HITS(I)
      IF(HITS(I).GE.3)SHKILL=SHKILL+1
      TARTOT(I)=TARTOT(I)+TARG(I)
870   CONTINUE
C
      IF(NBAT.LT.1)GO TO 875
      DO 880 I=1,NBAT
      IF((FIRCON(I,2).EQ.999999).AND.(MAGOP(FIRCON(I,3)).EQ.1))
     &   FCREM=FCREM+1
880   CONTINUE
875   CONTINUE
C
      DO 890 I=1,SOTOT
        IF(SELDEF(I,3).EQ.1)SOREM=SOREM+1
890   CONTINUE
C
      DO 900 I=1,6
        OFIRED(I)=CFIRED(I)+FIRED(I)
900   CONTINUE
C
      DO 910 I=1,ATTACK
        IF(CMRES(I,1).EQ.0)GO TO 920
        SYSKIL(CMRES(I,1))=SYSKIL(CMRES(I,1))+1
        KTOTAL(CMRES(I,2))=KTOTAL(CMRES(I,2))+1
        GO TO 910
920     CONTINUE
        ASCMH(I)=ASCMH(I)+1
910   CONTINUE
C     END OF LOOP ON REPLICATIONS LABEL 40
C
40    CONTINUE
C     ADJUST STORED RESULTS TO ACCOUNT FOR REPLICATIONS
C
      MAGREM=FLOAT(MAGRT)/F
      MAGLES=FLOAT(MAGORT)/F
      ONET(1)=ONET(1)/F
      ONET(2)=ONET(2)/F
      TWOT(1)=TWOT(1)/F
      TWOT(2)=TWOT(2)/F
C
      DO 930 I=1,NSHIPS
        IF(RNDREM(I).LT.1)GO TO 929
        RREM(I)=FLOAT(RNDREM(I))/F
929     CONTINUE
        HTOTAL(I)=(FLOAT(HTOTAL(I))/F)
        TARTOT(I)=( FLOAT(TARTOT(I))/F)
        KTOTAL(I)=(FLOAT(KTOTAL(I))/F)
```

```
  930   CONTINUE
C
        HITOF=  FLOAT(HITOT)/F
        SHKILF=  FLOAT(SHKILL)/F
        FCREF=  FLOAT(FCREM)/F
        SUREF=  FLOAT(SUREM)/F
C
        DO 940  I=1,6
            DFIREF(I)=  FLOAT(DFIRED(I))/F
            SYSKIF(I)=  FLOAT(SYSKIL(I))/F
  940   CONTINUE
C
        DO 950  I=1,ATTACK
             ASCMF(I)=FLOAT(ASCMH(I))/F
             CUMH(I)=0.0
             CUMP(I)=0.0
  950   CONTINUE
C
C
        CUMH(1)=ASCMF(1)
        CUMP(1)=ASCMF(1)
C
        IF(ATTACK.LT.2)GO TO 966
        DO 960  I=2,ATTACK
              CUMH(I)=ASCMF(I)+CUMH(I-1)
              CUMP(I)=0.0
              IF(CUMH(I).GT.0.0)CUMP(I)=CUMH(I)/FLOAT(I)
  960   CONTINUE
  966   CONTINUE
        IF(ATTACK.GE.210) GO TO 955
        N=ATTACK +1
        DO 952  I=N,210
             ASCMF(I)=0.0
  952   CONTINUE
  955   CONTINUE
C
C
        NSHIP=NSHIPS
        DO 942  I=1,NSHIPS
             IF(SPCLAS(I).EQ.99)HITOF=HITOF-HITAF(I)
             IF(STYPE(I).EQ.3)NSHIP=NSHIP-1
  942   CONTINUE
C
        PER1=0.0
        PER2=0.0
        PER3=0.0
        PER4=0.0
        PER5=0.0
```

```
      PER6=0.0
      IF(HITOF.EQ.0.0)GO TO 972
      PER1=HITOF/FLOAT(ATTACK)
  972 CONTINUE
      IF(SHKILF.EQ.0.0)GO TO 973
      PER2=SHKILF/NSHIP
  973 CONTINUE
      IF(FCREF.EQ.0.0)GO TO 974
      IF(NBAT.EQ.0)GO TO 974
      PER3=FCREF/FLOAT(NBAT)
  974 CONTINUE
      IF(SDREF.EQ.0.0)GO TO 975
      PER4=SDREF/FLOAT(SDTOT)
  975 CONTINUE
      IF(MAGREM.EQ.0.0)GO TO 976
      IF(MAGCAP.EQ.0)GO TO 976
      PER5=MAGREM/FLOAT(MAGCAP)
  976 CONTINUE
      IF(MAGDES.EQ.0.0)GO TO 977
      IF(MAGCAP.EQ.0)GO TO 977
      PER6=MAGDES/FLOAT(MAGCAP)
  977 CONTINUE
C
C*************************************************************************
C                  PRINTOUT SECTION
C*************************************************************************
      IF(SKIP.EQ.4)GO TO 999
      WRITE(6,1)
    1 FORMAT('1')
      WRITE(6,2)
    2 FORMAT(1X)
       WRITE(6,205)
  205  FORMAT(1X,T25,'**** L.A.S.H.A.D.S.  OUTPUT ****'/)
C
       WRITE(6,210)
  210   FORMAT(1X,T7,'ATTACK STATISTICS',T42,'DEFENSE STATISTICS'/)
C
      WRITE(6,215)ATTACK,NSHIP
  215 FORMAT(1X,'NUMBER OF ATTACKING ASCM',T30,I3,T35,'NUMBER OF',1X,
     & 'DEFENDING SHIPS',T70,I3)
C
      WRITE(6,220)CMCLAS,FIRERS
  220 FORMAT(1X,'ASCM MISSILE CLASSIFICATION',[illegible],'NUMBER OF',[illegible]
     &,'AREA DEF SHIPS',T70,I3)
C
      WRITE(6,225)TIMINT,NBAT
  225 FORMAT(1X,'SECONDS BETWEEN MISSILES',T2[illegible],F6.1,T35,'NUMBER OF AREA'
     &,1X,'DEFENSE BATTERIES',T70,I3)
```

```
C                                                                        AD 23050
      WRITE(6,230)NAVE,SDTCF                                             AD 23060
  230 FORMAT(1X,'NUMBER OF WAVES',T30,I3,T39,'NUMBER SELF DEFENSE',      AD 23070
     & 1X,'BATTERIES',T70,I3)                                            AD 23080
C                                                                        AD 23090
      WRITE(6,231)AUG,MAGCAP                                             AD 23100
  231 FORMAT(1X,'HVT TARGETING',T30,I3,T39,'NUMBER AREA DEFENSE',        AD 23110
     & 1X,'RNDS INIT',T70,I4)                                            AD 23120
C                                                                        AD 23130
      WRITE(6,232)HVIPER,RADAR                                           AD 23140
  232 FORMAT(1X,'PERCENT HVU TARGETING',T30,F6.2,T39,'RADAR RANGE',      AD 23150
     & T69,F6.1)                                                         AD 23160
C                                                                        AD 23170
      WRITE(6,233)HVIVUL,CYCLE(6)                                        AD 23180
  233 FORMAT(1X,'AUGMENT PERCENTAGE',T30,F6.2,T39,'ECM CYCLE TIME',      AD 23190
     & T69,F6.1/)                                                        AD 23200
C                                                                        AD 23210
      WRITE(6,212)REPS                                                   AD 23220
  212 FORMAT(1X,'RESULT OF THE ENGAGEMENT OVER ',I4,' REPLICATIONS')     AD 23230
C                                                                        AD 23240
      WRITE(6,214)                                                       AD 23250
  214 FORMAT(1X,T45,'PERCENT'/)                                          AD 23260
C                                                                        AD 23270
      WRITE(6,213)HITOF,PER1                                             AD 23280
  213 FORMAT(1X,'AVERAGE TOTAL HITS ON SHIPS',T35,F6.2,2X,F5.3)          AD 23290
C                                                                        AD 23300
      WRITE(6,216)SHKILF,PER2                                            AD 23310
  216 FORMAT(1X,'AVERAGE TOTAL SHIPS OOC',T35,F6.2,2X,F5.3)              AD 23320
C                                                                        AD 23330
      WRITE(6,217)FCRLF,PER3                                             AD 23340
  217 FORMAT(1X,'AREA DEF BATTERIES REMAINING',T35,F6.2,2X,F5.3)         AD 23350
C                                                                        AD 23360
      WRITE(6,218)SDRLF,PER4                                             AD 23370
  218 FORMAT(1X,'SELF DEF BATTERIES REMAINING',T35,F6.2,2X,F5.3)         AD 23380
C                                                                        AD 23390
      WRITE(6,219)MAGREM,PER5                                            AD 23400
  219 FORMAT(1X,'AREA DEF ROUNDS REMAINING',T35,F6.2,2X,F5.3)            AD 23410
C                                                                        AD 23420
      WRITE(6,221)MAGDES,PER6                                            AD 23430
  221 FORMAT(1X,'AREA DEF ROUNDS DESTROYED',T35,F6.2,2X,F5.3//)          AD 23440
      WRITE(6,235)                                                       AD 23450
  235 FORMAT(1X,'INDIVIDUAL SHIP STATISTICS'/)                           AD 23460
C                                                                        AD 23470
      WRITE(6,250)                                                       AD 23480
  250 FORMAT(1X,'NUMBER  CLASS  TYPE  POSITION  AXIS')                   AD 23490
C                                                                        AD 23500
      DO 240 I=1,NSHIPS                                                  AD 23510
         WRITE(6,245)NUM(I),SHCLAS(I),STYPE(I),SPOS(I),AXIS(I)           AD 23520
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245   FORMAT(1X,I4,I10,I3,T18,I1,T23,F6.2,T34,I2)
240   CONTINUE
C
      WRITE(6,2)
C
C
      WRITE(6,243)
243   FORMAT(1X,'SHIP  #1 BATS  #2 BATS  #PD SAM   #AC GUN    #CIWS',
     &'    #ECM')
      DO 241 I=1,NSHIPS
         WRITE(6,242)NUM(I),(SHWEPS(I,J),J=1,6)
242         FORMAT(1X,I3,T8,I2,5(8X,I2))
241   CONTINUE
C
      WRITE(6,2)
C
      WRITE(6,246)
246   FORMAT(1X,'SHIP  #TARGETED      #HITS       #KILLS   PNDS REM')
      DO 247 I=1,NSHIPS
         WRITE(6,248)NUM(I),TARTOT(I),HTOTAF(I),KTOTAF(I),RREM(I)
248      FORMAT(1X,I3,T8,F6.2,8X,F6.2,5X,F6.2,4X,F6.2)
247   CONTINUE
      WRITE(6,255)
255   FORMAT(1X,/)
C
      WRITE(6,258)
258   FORMAT(1X,'SYSTEM PERFORMANCE OF INDIVIDUAL DEFENSES'//)
C
      WRITE(6,259)
259   FORMAT(1X,T30,'KILLS',T39,'RDS EXP',T49,'# SINGLE',
     & T60,'# SALVO'/)
C
      WRITE(6,260)SYSKIF(1),DFIREF(1),ONET(1), TWOT(1)
260   FORMAT(1X,'LONG RANGE AIR DEFENSE SAM',T28,F6.2,T38,F6.2,
     &  T50,F6.2,T60,F6.2)
C
      WRITE(6,261)SYSKIF(2),DFIREF(2),ONET(2),TWOT(2)
261   FORMAT(1X,'INT RANGE AIR DEFENSE SAM',T28,F6.2,T38,F6.2,
     &  T50,F6.2,T60,F6.2)
C
      WRITE(6,262)SYSKIF(3),DFIREF(3)
262   FORMAT(1X,'POINT DEFENSE SAM',T28,F6.2,T38,F6.2)
C
      WRITE(6,263)SYSKIF(4),DFIREF(4)
263   FORMAT(1X,'MEDIUM CALIPER GUN',T28,F6.2,T38,F6.2)
C
      WRITE(6,264)SYSKIF(5),DFIREF(5)
264   FORMAT(1X,'CIWS GUN',T28,F6.2,T38,F6.2)
```

```
C
      WRITE(6,265)SYSKIF(S),DFIREF(6)
 265  FORMAT(1X,'ELECTRONIC COUNTERMEASURES',T28,F8.2,T33,F6.2)
C
C     THE NEXT SECTION PLOTS A CURVE OF THE HIT PERCENTAGE PER MISS
C
      IF(SKIP.EQ.1)GO TO 999
      WRITE(6,1)
C
      WRITE(6,270)
 270  FORMAT(1X,'MISSILE REACHES SHIP TARGET- PERCENTAGE'//)
C
      WRITE(6,2)
      WRITE(6,275)
 275  FORMAT(1X,'  ASCM  %&  CUM HIT  CUM%'/)
C
      DO 280 I=1,70
          WRITE(6,285)NUM(I),ASCMF(I),CUMH(I),CUMP(I),
     &                NUM(I+70 ),ASCMF(I+70 ),CUMH(I+70 ),CUMP(I+70 ),
     &                NUM(I+140),ASCMF(I+140),CUMH(I+140),CUMP(I+140)
 285      FORMAT(1X,3(3X,I3,1X,F5.3,1X,F6.2,1X,F5.3))
 280  CONTINUE
      IF(SKIP.EQ.2)GO TO 999
C*********************** ************************ ****************
C         END  OUTPUT SECTION
C************************ ************************ ***************
C     RESULT(1,SS,AA)=PER1
C     RESULT(2,SS,AA)=PER2
C     RESULT(3,SS,AA)=PER3
C     RESULT(4,SS,AA)=PER4
C     RESULT(5,SS,AA)=PER5
C     RESULT(6,SS,AA)=PER6
C     NRES(1,SS,AA)=HITOF
C     NRES(2,SS,AA)=SHKILF
C     NRES(3,SS,AA)=FCREF
C     NRES(4,SS,AA)=SUREF
C     NRES(5,SS,AA)=MAGREM
C     NRES(6,SS,AA)=MAGDES
C
C     ************** GRAPH PRINTOUT SECTION
      DO 286 I=1,120
C         GRES1(I)=CUMP(I)
C         GRES2(I)=CUMH(I)
          GRES3(I)=ASCMF(I)
 286  CONTINUE
C     WRITE(6,1)
C     WRITE(6,600)SHCLAS(SS)
C600  FORMAT(1X,'SHIP CLASS ',I2,' ASCM#2 I1=1000.)  ( PERCENT')
```

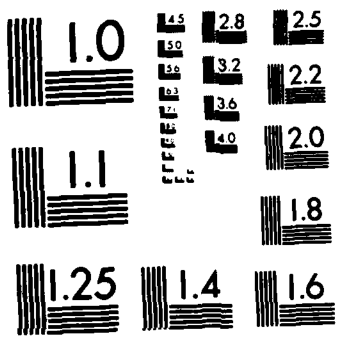
```
C        CALL PLOTP(GNUM,GRES1,80,8)
C        WRITE(6,1)
C        WRITE(6,601)SHCLAS(SS)
C601     FORMAT(1X,'SHIP CLASS ',I2,' ASCM=2 TI=1000.0  COM HITS')
C        CALL PLOTP(GNUM,GRES2,80,8)
C           **** HERE DOWN FOR PROPER GRAPH
         WRITE(6,1)
         WRITE(6,606)SHCLAS( I),CMCLAS,TIMINT
 606     FORMAT(1X,'SHIP CLASS ',I2,' ASCM= ',I2,'TIME INTERVAL= ',
     &          F6.1,' HIT PERCENT WRT MISSILE NUMBER'/)
         CALL PLOTP(GNUM,GRES3,120,8)
C           **** END PROPER GRAPH
C        WRITE(6,602)SS,SYSKIF(1),SYSKIF(2),KTOTAF(1),PK(1,1)
C602     FORMAT(1X,I2,4(3X,F6.2))
  599    CONTINUE
C ********************TAILORED FOR CAP AND COLLAPSE VAL
         M=0
         N=0
         DO 599 I=1,ATTACK
              IF(ASCMF( I).GT.0.1)GO TO 601
              M=M+1
  601         CONTINUE
              IF(ASCMF( I).GT.0.5)GO TO 602
              N=N+1
  602         CONTINUE
  599    CONTINUE
         WRITE(6,603)M,N
  603    FORMAT(1X,'CAP=',I5,4X,'COL=',I5)
C       ***************END TAILORED FOR CAP AND COLLAPSE VALUES
C6       CONTINUE
C5       CONTINUE
C7       CONTINUE
         STOP
         END
C
C
C
         SUBROUTINE ROLL(RAN,RAND,IXT)
         INTEGER RAN,IXT,IX
         REAL*4 RAND(1000)
         IXT=IXT+1
         RAN=1
         IX=IXT+1:13
         CALL LRNC(IX,RAND,1000,2,0)
         RETURN
         END
```

```
C     ************************************************************
C     *                                                          *
C     *                         SUMS                             *
C     *                                                          *
C     * A DETERMINISTIC MODEL USING AAW FIREPOWER INDICES        *
C     *   FOR DETERMINING THE RESULTS OF ASCM ENGAGEMENTS        *
C     *     ALAN D. ZIMM LCDR USN  1 SEPTEMBER 1983              *
C     ************************************************************
C
C
C
C
C
      REAL LEAK, PK,SATL,SATJ, TIMINT, UADEG, SHIP(24,7), CAP
      REAL FILE(24,7), PRES(5,4),PKV(9), COLL, COLU,INFSL, INTERC(5)
      REAL INFSU, INFCL, INFCU,LEAK, SAT, COL, HITS, AA,LAYER
C
      INTEGER ATTACK, NSHIPS, SHCLAS(20), AXIS(20), INTER, NATION
      INTEGER I,J, A,R, ASHIPS
C
C
C
      DO 900 R=1,10
C
C     * ENTER NUMBER OF SHIPS, INTEGER
      NSHIPS= 6
C
C     * ENTER CLASS OF SHIPS, INTEGER
      SHCLAS( 1)=17
      SHCLAS( 2)=18
      SHCLAS( 3)=18
      SHCLAS( 4)=16
      SHCLAS( 5)=21
      SHCLAS( 6)=22
      SHCLAS( 7)=7
      SHCLAS( 8)=8
      SHCLAS( 9)=9
      SHCLAS(10)=9
      SHCLAS(11)=1
      SHCLAS(12)=1
      SHCLAS(13)=1
      SHCLAS(14)=1
      SHCLAS(15)=1
      SHCLAS(16)=1
      SHCLAS(17)=1
      SHCLAS(18)=1
      SHCLAS(19)=1
      SHCLAS(20)=1
```

```
C
C       ENTER AXIS (ON=0, OFF=1)
        AXIS( 1)=0
        AXIS( 2)=0
        AXIS( 3)=1
        AXIS( 4)=0
        AXIS( 5)=0
        AXIS( 6)=1
        AXIS( 7)=1
        AXIS( 8)=0
        AXIS( 9)=1
        AXIS(10)=0
        AXIS(11)=0
        AXIS(12)=0
        AXIS(13)=0
        AXIS(14)=0
        AXIS(15)=0
        AXIS(16)=0
        AXIS(17)=0
        AXIS(18)=0
        AXIS(19)=0
        AXIS(20)=0
C
C       ENTER NUMBER OF LAYERS OF SHIPS COMPOSING THE DEFENSE
        LAYER=3.0
C
C       * ENTER P-K OF DEFENDING AREA DEFENSE SAM
        PK=.7
C
C     * ENTER NATIONALITY (U.S. = 1, SOVIET = 2)
        NATION=2
C
C       * ENTER NUMBER OF INTERCEPTS (1-5, INTEGER)
        INTER=5
C
C       * ENTER NUMBER OF MISSILES, INTEGER
        ATTACK=10*R
C
C       * ENTER TIME INTERVAL BETWEEN ASCM, REAL, SECONDS
        TIMINT= 2.0
C
C       * ENTER CAPABILITY OF ATTACKING ASCM ("DIFFICULTY")
        CAP=1.0
C
C       ********************************************
C       END INPUT SECTION
C       ********************************************
C
```

AD-A138 781 AAW FIREPOWER INDEXING FOR NAVAL COMBATANTS(U) NAVAL POSTGRADUATE SCHOOL MONTEREY CA A D ZIMM SEP 83 3/3

UNCLASSIFIED F/G 15/7 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

```
C         START  INITIALIZATION SECTION                                  SUM00970
C                                                                        SUM00980
          SHIP( 1,1)=.06                                                 SUM00990
          SHIP( 2,1)=.02                                                 SUM01000
          SHIP( 3,1)=.02                                                 SUM01010
          SHIP( 4,1)=.02                                                 SUM01020
          SHIP( 5,1)=.04                                                 SUM01030
          SHIP( 6,1)=.03                                                 SUM01040
          SHIP( 7,1)=.06                                                 SUM01050
          SHIP( 8,1)=.03                                                 SUM01060
          SHIP( 9,1)=.13                                                 SUM01070
          SHIP(10,1)=.02                                                 SUM01080
          SHIP(11,1)=.01                                                 SUM01090
          SHIP(12,1)=.01                                                 SUM01100
          SHIP(13,1)=.01                                                 SUM01110
          SHIP(14,1)=.01                                                 SUM01120
          SHIP(15,1)=.02                                                 SUM01130
          SHIP(16,1)=.07                                                 SUM01140
          SHIP(17,1)=.02                                                 SUM01150
          SHIP(18,1)=.02                                                 SUM01160
          SHIP(19,1)=.02                                                 SUM01170
          SHIP(20,1)=.02                                                 SUM01180
          SHIP(21,1)=.02                                                 SUM01190
          SHIP(22,1)=.23                                                 SUM01200
          SHIP(23,1)=.0                                                  SUM01210
          SHIP(24,1)=.02                                                 SUM01220
          SHIP( 1,2)= 2.0                                                SUM01230
          SHIP( 2,2)= 5.0                                                SUM01240
          SHIP( 3,2)= 4.0                                                SUM01250
          SHIP( 4,2)= 6.0                                                SUM01260
          SHIP( 5,2)= 3.0                                                SUM01270
          SHIP( 6,2)= 4.0                                                SUM01280
          SHIP( 7,2)= 1.0                                                SUM01290
          SHIP( 8,2)= 2.0                                                SUM01300
          SHIP( 9,2)= 1.0                                                SUM01310
          SHIP(10,2)=30.0                                                SUM01320
          SHIP(11,2)=31.0                                                SUM01330
          SHIP(12,2)=33.0                                                SUM01340
          SHIP(13,2)= 4.0                                                SUM01350
          SHIP(14,2)=16.0                                                SUM01360
          SHIP(15,2)= 5.0                                                SUM01370
          SHIP(16,2)= 2.0                                                SUM01380
          SHIP(17,2)= 4.0                                                SUM01390
          SHIP(18,2)= 4.0                                                SUM01400
          SHIP(19,2)= 3.0                                                SUM01410
          SHIP(20,2)= 1.0                                                SUM01420
          SHIP(21,2)= 3.0                                                SUM01430
          SHIP(22,2)= 1.0                                                SUM01440
```

```
      SHIP(23,2)= 1.0                                        SUM01450
      SHIP(24,2)= 6.0                                        SUM01460
      SHIP( 1,3)= 8.0                                        SUM01470
      SHIP( 2,3)=37.0                                        SUM01480
      SHIP( 3,3)=27.0                                        SUM01490
      SHIP( 4,3)=51.0                                        SUM01500
      SHIP( 5,3)=22.0                                        SUM01510
      SHIP( 6,3)=26.0                                        SUM01520
      SHIP( 7,3)=4 .0                                        SUM01530
      SHIP( 8,3)=19.0                                        SUM01540
      SHIP( 9,3)= 1.0                                        SUM01550
      SHIP(10,3)=60.0                                        SUM01560
      SHIP(11,3)=71.0                                        SUM01570
      SHIP(12,3)=74.0                                        SUM01580
      SHIP(13,3)=47.0                                        SUM01590
      SHIP(14,3)=48.0                                        SUM01600
      SHIP(15,3)=25.0                                        SUM01610
      SHIP(16,3)= 6.0                                        SUM01620
      SHIP(17,3)=28.0                                        SUM01630
      SHIP(18,3)=31.0                                        SUM01640
      SHIP(19,3)=25.0                                        SUM01650
      SHIP(20,3)=11.0                                        SUM01660
      SHIP(21,3)=25.0                                        SUM01670
      SHIP(22,3)= 1.0                                        SUM01680
      SHIP(23,3)= 1.0                                        SUM01690
      SHIP(24,3)=48.0                                        SUM01700
      SHIP( 1,4)= 4.0                                        SUM01710
      SHIP( 2,4)= 7.0                                        SUM01720
      SHIP( 3,4)= 6.0                                        SUM01730
      SHIP( 4,4)= 8.0                                        SUM01740
      SHIP( 5,4)= 4.0                                        SUM01750
      SHIP( 6,4)= 6.0                                        SUM01760
      SHIP( 7,4)= 3.0                                        SUM01770
      SHIP( 8,4)= 4.0                                        SUM01780
      SHIP( 9,4)= 2.0                                        SUM01790
      SHIP(10,4)=34.0                                        SUM01800
      SHIP(11,4)=34.0                                        SUM01810
      SHIP(12,4)=38.0                                        SUM01820
      SHIP(13,4)= 6.0                                        SUM01830
      SHIP(14,4)=18.0                                        SUM01840
      SHIP(15,4)= 6.0                                        SUM01850
      SHIP(16,4)= 3.0                                        SUM01860
      SHIP(17,4)= 6.0                                        SUM01870
      SHIP(18,4)= 6.0                                        SUM01880
      SHIP(19,4)= 5.0                                        SUM01890
      SHIP(20,4)= 2.0                                        SUM01900
      SHIP(21,4)= 5.0                                        SUM01910
      SHIP(22,4)= 2.0                                        SUM01920
```

```
      SHIP(23,4)= 1.0                                           SUM01930
      SHIP(24,4)= 8.0                                           SUM01940
      SHIP( 1,5)=13.0                                           SUM01950
      SHIP( 2,5)=45.0                                           SUM01960
      SHIP( 3,5)=32.0                                           SUM01970
      SHIP( 4,5)=60.0                                           SUM01980
      SHIP( 5,5)=27.0                                           SUM01990
      SHIP( 6,5)=30.0                                           SUM02000
      SHIP( 7,5)= 7.0                                           SUM02010
      SHIP( 8,5)=24.0                                           SUM02020
      SHIP( 9,5)= 5.0                                           SUM02030
      SHIP(10,5)=71.0                                           SUM02040
      SHIP(11,5)=85.0                                           SUM02050
      SHIP(12,5)=94.0                                           SUM02060
      SHIP(13,5)=57.0                                           SUM02070
      SHIP(14,5)=62.0                                           SUM02080
      SHIP(15,5)=31.0                                           SUM02090
      SHIP(16,5)=20.0                                           SUM02100
      SHIP(17,5)=39.0                                           SUM02110
      SHIP(18,5)=38.0                                           SUM02120
      SHIP(19,5)=31.0                                           SUM02130
      SHIP(20,5)=14.0                                           SUM02140
      SHIP(21,5)=31.0                                           SUM02150
      SHIP(22,5)= 9.0                                           SUM02160
      SHIP(23,5)= 1.0                                           SUM02170
      SHIP(24,5)=57.0                                           SUM02180
      SHIP( 1,6)= 1.0                                           SUM02190
      SHIP( 2,6)= 1.0                                           SUM02200
      SHIP( 3,6)= 1.0                                           SUM02210
      SHIP( 4,6)= 1.0                                           SUM02220
      SHIP( 5,6)= 1.0                                           SUM02230
      SHIP( 6,6)= 1.0                                           SUM02240
      SHIP( 7,6)= 1.0                                           SUM02250
      SHIP( 8,6)= 1.0                                           SUM02260
      SHIP( 9,6)= 1.0                                           SUM02270
      SHIP(10,6)= 1.0                                           SUM02280
      SHIP(11,6)= 2.0                                           SUM02290
      SHIP(12,6)= 2.0                                           SUM02300
      SHIP(13,6)= 2.0                                           SUM02310
      SHIP(14,6)= 2.0                                           SUM02320
      SHIP(15,6)= 2.0                                           SUM02330
      SHIP(16,6)= 2.0                                           SUM02340
      SHIP(17,6)= 2.0                                           SUM02350
      SHIP(18,6)= 2.0                                           SUM02360
      SHIP(19,6)= 2.0                                           SUM02370
      SHIP(20,6)= 2.0                                           SUM02380
      SHIP(21,6)= 2.0                                           SUM02390
      SHIP(22,6)= 2.0                                           SUM02400
```

```
SHIP(23,6)= 2.0                                   SUM02410
SHIP(24,6)= 1.0                                   SUM02420
SHIP( 1,7)= 0.0                                   SUM02430
SHIP( 2,7)= 1.0                                   SUM02440
SHIP( 3,7)= 1.0                                   SUM02450
SHIP( 4,7)= 1.0                                   SUM02460
SHIP( 5,7)= 2.0                                   SUM02470
SHIP( 6,7)= 1.0                                   SUM02480
SHIP( 7,7)= 0.0                                   SUM02490
SHIP( 8,7)= 2.0                                   SUM02500
SHIP( 9,7)= 0.0                                   SUM02510
SHIP(10,7)= 2.0                                   SUM02520
SHIP(11,7)= 1.0                                   SUM02530
SHIP(12,7)= 1.0                                   SUM02540
SHIP(13,7)= 2.0                                   SUM02550
SHIP(14,7)= 1.0                                   SUM02560
SHIP(15,7)= 1.0                                   SUM02570
SHIP(16,7)= 0.0                                   SUM02580
SHIP(17,7)= 2.0                                   SUM02590
SHIP(18,7)= 2.0                                   SUM02600
SHIP(19,7)= 2.0                                   SUM02610
SHIP(20,7)= 2.0                                   SUM02620
SHIP(21,7)= 2.0                                   SUM02630
SHIP(22,7)= 0.0                                   SUM02640
SHIP(23,7)= 0.0                                   SUM02650
SHIP(24,7)= 2.0                                   SUM02660
PKV(1)=0.612                                      SUM02670
PKV(2)=0.711                                      SUM02680
PKV(3)=0.816                                      SUM02690
PKV(4)=0.882                                      SUM02700
PKV(5)=0.936                                      SUM02710
PKV(6)=0.975                                      SUM02720
PKV(7)=1.0                                        SUM02730
PKV(8)=1.02                                       SUM02740
PKV(9)=1.033                                      SUM02750
INTERC(1)=3.0                                     SUM02760
INTERC(2)=2.0                                     SUM02770
INTERC(3)=1.0                                     SUM02780
INTERC(4)=1.0                                     SUM02790
INTERC(5)=1.0                                     SUM02800
PRES(1,1)= 0.32                                   SUM02810
PRES(1,2)= 0.7                                    SUM02820
PRES(1,3)= 0.33                                   SUM02830
PRES(1,4)= 0.72                                   SUM02840
PRES(2,1)= 0.6                                    SUM02850
PRES(2,2)= 0.9                                    SUM02860
PRES(2,3)= 0.66                                   SUM02870
PRES(2,4)= 0.92                                   SUM02880
```

```
      PRES(3,1)= 1.0
      PRES(3,2)= 1.0
      PRES(3,3)= 1.0
      PRES(3,4)= 1.0
      PRES(4,1)= 1.23
      PRES(4,2)= 1.07
      PRES(4,3)= 1.36
      PRES(4,4)= 1.09
      PRES(5,1)= 1.26
      PRES(5,2)= 1.09
      PRES(5,3)= 1.39
      PRES(5,4)= 1.11
C
C     CUMMENCE COMPUTATIONS
C
      ASHIPS=NSHIPS
      HITS=0.0
C
C
      DO 10 I=1,NSHIPS
          IF(SHIP(I,7).LT.0.5)ASHIPS=ASHIPS-1
          DO 20 J=1,7
              FILE(I,J)=SHIP(SHCLAS(I),J)
   20     CONTINUE
   10 CONTINUE
C
      DO 30 I=1,NSHIPS
          DO 40 J=2,5
              FILE(I,J)=FILE(I,J)*PKV(IFIX(PK/0.1))*(PK/.7)
   40     CONTINUE
   30 CONTINUE
C
      DO 50 I=1,NSHIPS
          DO 60 J=2,3
              IF(FILE(I,J).EQ.0)GO TO 60
              IF(NATION.EQ.2) GO TO 80
                  IF((INTER.GE.3).AND.(FILE(I,7).EQ.2))GO TO 60
                FILE(I,J)=FILE(I,J)*PRES(INTER,1)
                FILE(I,J+2)=FILE(I,J+2)*PRES(INTER,2)
                GO TO 60
   80         CONTINUE
                  IF((INTER.GE.3).AND.(FILE(I,7).EQ.2))GO TO 60
                FILE(I,J)=FILE(I,J)*PRES(INTER,3)
                FILE(I,J+2)=FILE(I,J+2)*PRES(INTER,4)
   60     CONTINUE
   50 CONTINUE
C
C
```

```
      DO 100  I=1,NSHIPS                                                SUM03370
          DO 110  J=2,5                                                 SUM03380
              IF(AXIS(I).NE.0)FILE(I,J)=FILE(I,J)*.8                    SUM03390
  110     CONTINUE                                                      SUM03400
  100 CONTINUE                                                          SUM03410
C                                                                       SUM03420
      SATU=0.0                                                          SUM03430
      SATL=0.0                                                          SUM03440
      COLL=0.0                                                          SUM03450
      COLU=0.0                                                          SUM03460
C                                                                       SUM03470
      DO 120  I=1,NSHIPS                                                SUM03480
          SATL=SATL+FILE(I,2)                                           SUM03490
          SATU=SATL+FILE(I,3)                                           SUM03500
          COLL=COLL+FILE(I,4)                                           SUM03510
          COLU=COLU+FILE(I,5)                                           SUM03520
  120 CONTINUE                                                          SUM03530
C                                                                       SUM03540
      WRITE(6,205)SATL,SATU,COLL,COLU                                   SUM03550
  205 FORMAT(1X,4(3X,F7.2))                                             SUM03560
      IF(NSHIPS.GT.1)SATU=SATU*.8                                       SUM03570
      IF(NSHIPS.GT.1)SATL=SATL*.8                                       SUM03580
C                                                                       SUM03590
      INFSL=20.0/FLOAT(ASHIPS)                                          SUM03600
      INFSU=80.0/FLOAT(ASHIPS)                                          SUM03610
      INFCL=10.0/FLOAT(ASHIPS)-( 5.0/FLOAT(ASHIPS))                     SUM03620
      INFCU=70.0/FLOAT(ASHIPS)-(10.0/FLOAT(ASHIPS))                     SUM03630
      WRITE(6,205)INFSL,INFSU,INFCL,INFCU                               SUM03640
C                                                                       SUM03650
      J=0                                                               SUM03660
      LEAK=0.0                                                          SUM03670
C                                                                       SUM03680
      DO 130  I=1, NSHIPS                                               SUM03690
          IF(FILE(I,7).EQ.0)GO TO 140                                   SUM03700
            J=J+1                                                       SUM03710
            LEAK= LEAK+((FILE(I,1)*INTERC(INTER))/FLOAT(NSHIPS))        SUM03720
            GO TO 130                                                   SUM03730
  140     CONTINUE                                                      SUM03740
          LEAK=LEAK+(FILE(I,1)/FLOAT(NSHIPS))                           SUM03750
  130 CONTINUE                                                          SUM03760
C                                                                       SUM03770
      LEAK=(LEAK*CAP)/LAYER                                             SUM03780
C                                                                       SUM03790
      IF(TIMINT.LT.INFSL)GO TO 150                                      SUM03800
      SATL=SATL+(((TIMINT-INFSL)/(INFSU-INFSL))*(SATU-SATL))            SUM03810
  150 CONTINUE                                                          SUM03820
      SAT=SATL                                                          SUM03830
  160 CONTINUE                                                          SUM03840
```

```
      COL=COLL
      IF(TIMINT.LT.INFCL)GO TO 170
      COL=COLL+(((TIMINT-INFCL)/(INFCU-INFCL))*(COLU-COLL))
170   CONTINUE
      IF(ATTACK.GT.IFIX(SAT))GO TO 180
      HITS=LEAK*FLOAT(ATTACK)
      GO TO 190
180   CONTINUE
      HITS=LEAK*SAT
      A=(ATTACK-IFIX(SAT))+1
      AA=0.1
      DO 185 I=1,A
         AA=AA+(.4/(COL-SAT))
         IF(AA.GT.1.0)AA=1.0
         HITS=HITS+AA
185   CONTINUE
190   CONTINUE
C
       WRITE(6,200)ATTACK, TIMINT, SAT, COL, HITS,LEAK
200    FORMAT(1X,'ATTACK= ',I3,' TIMINT= ', F6.2,' SAT= ',F6.2,
     &   ' COL= ',F6.2,' HITS= ',F7.2,' LEAK= ',F6.3)
500   CONTINUE
      STOP
      END
```

LIST OF REFERENCES

1. Taylor, J. G., Force-On-Force Attrition Modeling, Military Applications Section, Operations Research Society of America, 1981.

2. Dupuy, T. N., Numbers Predictions and War, Bobbs-Merrill, 1979.

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